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EFFECTIVENESS OF BUSERELIN IN EARLY PUERPERIUM ON RESTORATION OF OVARIAN CYCLICITY AND SUBSEQUENT CONCEPTION IN PRIMIPAROUS DAIRY COWS

Benjamin ČENGIĆ[1]*, Almedin HERCEGOVAC[2], Tarik MUTEVELIĆ[1], Amel ĆUTUK[1], Lejla VELIĆ[3], Aida GLAVINIĆ[1], Pamela BEJDIĆ[4], Amina HRKOVIĆ-POROBIJA[4]

[1]Veterinary Faculty, University of Sarajevo, Department for Clinical Sciences in Veterinary Medicine, Zmaja od Bosne 90, 71000 Sarajevo, Bosnia and Herzegovina
[2]Dairy farm "Spreča"; Gornje Vukovije, 75260 Kalesija, Bosnia and Herzegovina
[3]Veterinary Faculty, University of Sarajevo, Department of Pathobiology and Epidemiology, Zmaja od Bosne 90, 71000 Sarajevo, Bosnia and Herzegovina
[4]Veterinary Faculty, University of Sarajevo, Department of Basic Sciences in Veterinary Medicine, Zmaja od Bosne 90, 71000 Sarajevo, Bosnia and Herzegovina
*Corresponding author: benjamin.cengic@vfs.unsa.ba

ABSTRACT

The postpartum period is an important period in the reproductive life of both dairy and beef cows due to its great influence on subsequent pregnancies. A major reproductive problem on dairy farms is the delayed restoration of postpartum ovarian activity, which is reflected in a prolonged intercalving interval, where farmers suffer large economic losses. Dairy cows have between two and five months after parturition to become pregnant again if reproductive capacity and productivity are to be kept in desirable range. Utilisation of hormones is quite common in dairy industry, but to achieve improvement in reproductive performances they have to be used with caution. The study was focused on the restoration of the ovarian cyclicity in the early postpartum period and the reduction of the service period, where a total of 50 primiparous Simmental cows were divided into experimental and control groups. The experimental group was treated with the hormone buserelin, hormonal MSD preparation - Receptal®, which is a GnRH agonist was used in dose of 5 ml on the 10th, 11th, 12th, 13th or 14th day postpartum for earlier restoration of ovarian cyclicity. It is expected that about 30-40 heifers will require some assistance during parturition. A slightly higher number of animals had earlier restoration of ovarian cyclicity and had more conception in the experimental group in contrast to the control group. Buserelin applied at day 13^{th} or 14^{th} looks to be relatively efficient in shortening the service period and intercalving interval in primiparous simmental cows.

Keywords: *primiparous cow, buserelin, ovarian cyclicity, service period.*

INTRODUCTION

A major reproductive problem on dairy farms is the delayed restoration of postpartum ovarian activity, which is reflected in a prolonged service period and intercalving interval, where farmers suffer large economic losses. In order to improve the reproductive parameters of cows, various hormonal methods are used to establish and regulate the sexual cycle. Hormonal therapy must be accompanied by adequate nutrition. GnRH and PGF2α can certainly improve the reproductive results of cows only if proper nutrition is included, especially when milk production increases. Body condition at parturition has a direct positive influence on the restoration of ovarian cyclicity after calving. One of the most common reasons for postpartum anestrus is the sudden loss of the cow's body mass as a result of a negative energy balance and due to an increase in milk production during first 2-3 months of lactation. This is result of a direct connection of a negative energy balance to the inhibition of GnRH release (Peter and Ambrose, 2009). Any deviation in the length of the estrus cycle is considered pathological. Factors affecting the length of the estrus cycle can be of different etiologies such as temperature or transport stress, but also diseases of the reproductive system. Any hormonal therapy cannot correct deficiencies in the management itself. The postpartum period is an important period in the reproductive life of both dairy and beef cows due to its great influence on subsequent pregnancies. The entire postpartum period or puerperium, is defined as the period from birth until reproductive organs return to their normal anatomical and histological condition. Any prolongation of the puerperium in cows could have a detrimental effect on reproductive performance. Essentially, the determination of this period basically depends on the continuation of normal cycles on the ovaries, the manifestation of estrus and conception (Stevenson, 2014). Dairy cows have between two and five months after parturition to become pregnant again if reproductive capacity and productivity are to be kept in desirable range. To achieve this goal in dairy cows, it is necessary to bring the ovaries and uterus back to a normal physiological state that will allow conception (Mutevelić et al., 2019). In extensive ways of keeping dairy cows, it is assumed that about 75% of cows with very high milk yield will have an extended time to restore cyclicity and between 20 and 48% of cows manifest prolonged postpartum anestrus (Peter and Ambrose, 2009). Inadequate climatic factors, high milk production, poor physical condition, poor housing conditions, inadequate nutrition qualitatively and quantitatively represent significant factors that influence the prolongation of the interval from parturition to the first ovulation. Also, as a result of these factors, postpartum disorders and diseases of infectious and non-infectious etiologies, affect the first appearance of estrus postpartum (Shresthaa, 2004). All the listed factors directly influence the prolongation of the inhibition of the release of pituitary gonadotrophins (LH and FSH), which consequently delays the normal development and ovulation of the dominant follicle and the function of the *corpus luteum*. Our research is focused on the restoration of the ovarian cyclicity in the early post-partum period and the reduction of the service period.

MATERIALS AND METHODS

The research was conducted in the modern farm conditions for production of dairy cows "Spreča", Gornje Vukovije, Tuzla Canton in Bosnia and Herzegovina, where dairy cows of the Holstein-Friesian and Simental breeds are bred in free stall system.

The feed consists of winter and summer meals and milking is done three times daily with the DeLaVal system. Veterinary technicians are responsible for the daily inspection of cows in production and detection of estrus. In doubtful cases, veterinary doctors re-examine such cows. Insemination of cows is done on average 60 to 80 days postpartum and based on the assessment of the doctor of veterinary medicine on the farm, some inseminations can be performed even earlier depending on the general condition of the cow.

Our research included a total of 50 primiparous Simental cows, divided into experimental and control groups. The experimental group was divided into cows that were treated with the hormone buserelin (Receptal®) on the 10th, 11th, 12th, 13th or 14th day postpartum for earlier recovery of ovarian cyclicity. The period of the study was autumn/winter of 2020/2021.

For the application of buserelin, the hormonal MSD preparation - Receptal®, which is a GnRH agonist, was used (1 ml of injection solution contains 0.0042 mg of buserelin acetate - 0.004 mg of buserelin and 20.0 mg of benzyl alcohol). For the treatment, he manufacturer's recommended dose of 5ml in the early post partum period was used.

Research was conducted after dividing the experimental cows into 5 groups, i.e. on which day postpartum they received Receptal. The first group was administered on the 10th day postpartum (n=5), the second on the 11th day postpartum (n=5), the third on the 12th day postpartum (n=5), the fourth on the 13th day postpartum (n=5) and on the fifth, 14th day postpartum (n=5). All primiparous cows that had parturitions with or without the assistance of a veterinary doctor participated in the research. The control group consisted also of 25 primiparous cows. All cows in the study were monitored in the postpartum period of 20-30 days, when a transrectal ultrasonographic examination was performed to detect changes in the ovaries for cyclicity. In the period 40-100 days postpartum, artificial insemination was performed and a pregnancy examinations were performed 40- 50 days later.

Statistical data processing was carried out using the t-test to determine the significance of differences.

RESULTS AND DISCUSSION

Research showed that out of 25 pregnant heifers in the experimental and control group, 11 (44%) animals of the experimental and 8 (32%) animals of the control group needed assistance during calving to correct the position of the fetus and provide more power for extraction.

Table 1. The number of primiparous cows of the experimental and control groups that had a difficult parturition.

	Experimental group	**Control group**
Heifers with assistance during parturition	11 (44%)	8 (32%)
Heifers without assistance during parturition	14 (56%)	17 (68%)
Total number of heifers	25	25

Clinical examination of the ovarian status and the established number of cyclic cows after the Receptal application on the 10th, 11th, 12th, 13th or 14th day post partum and the control group. The first three groups have mostly the same or similar values compared to the control group, while groups 4 and 5 have slightly higher values – more cyclic cows compared to the control group.

Table 2. Established number of cyclic cows in experimental groups and their controls.

Confirmed cyclicity on day PP	**Group 1.**	**Con.**	**Group 2.**	**Con.**	**Group 3.**	**Con.**	**Group 4.**	**Con.**	**Group 5.**	**Con.**
20-25	3	2	2	2	2	1	4	2	3	2
30	2	1	3	2	2	3	4	3	4	2

For the first three groups the results are identical as their control, while groups 4 and 5 have a slightly higher values – more pregnancies compared to the control group.

Table 3. Number of pregnant and non pregnant cows in experimental groups and control animals after artificial insemination performed 40-100 days post partum (PP).

AI 40-100 days PP		**Pregnant**		**Not pregnant**	
Group 1	Control	2	2	3	3
Group 2	Control	2	2	3	3
Group 3	Control	2	2	3	3
Group 4	Control	3	2	2	3
Group 5	Control	4	2	1	3

A slightly higher number of animals conceived in the groups that received Receptal, in contrast to the conception of the control group. Also, the number of cows treated with Receptal, which did not conceive in the period 40 to 100 days post partum when artificial insemination was performed, does not differ much from the number of cows that did not conceive in the control group.
The results of ovarian cyclicity after the application of Receptal in the post partum period and the success of artificial insemination have no significant differences

compared to control cows, so this result is not significant (p <.05), which is caused by the small number of treated cows that were available at the given time for the research.

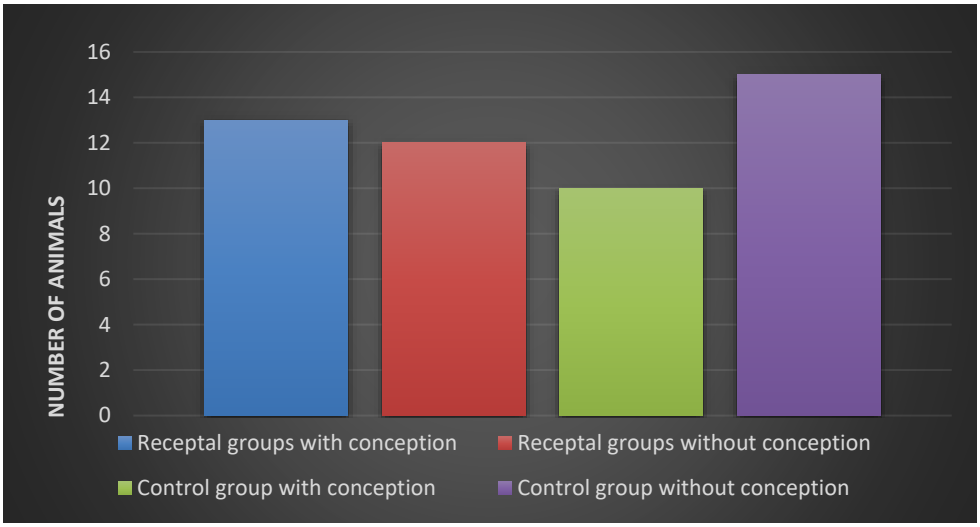

Chart 1. The chart shows the conception of primiparous cows treated with Receptal compared to the control group of primiparous cows.

The postpartum period has an important impact on reproductive performance. Despite all efforts and scientific knowledge, the fertility of dairy cows is constantly declining. Ovarian inactivity and postpartum uterine diseases, which later lead to postpartum anestrus are taken as the main contributing factor. Factors such as limited energy intake, lower body condition and postpartum diseases delay ovarian cyclicity and postpartum anestrus is common in dairy herds with high milk production. The restored cyclicity of the ovaries postpartum is influenced by the secretion of pituitary gonadotrophins (FSH and LH). In healthy cows, it is restored between the 2nd and 4th week postpartum and according to Reist et al. (2008), over 80% of cows should normally restore ovarian cyclicity within the first 35 days postpartum, which coincides with our research, while ovarian cyclicity was observed somewhat later in control cows.

After a normal parturition, according to Wattiaux (1996), the first ovulation occurs on average after the day 15th, the second on the day 32nd and the third on the day 53rd postpartum. The author points out that the first postpartum ovulation occurs as a silent one, without external signs of estrus as a normal occurrence in 76% of cows, which is consistent with our research in which we did not observe ovulation until the 15th day postpartum in both groups of cows. Our results also agree with Crowe (2008) where visible estrus is found on the day 32 (50% cows) and day 53rd (90% cows) postpartum.

In the research from Jeffrey and Benmrad (1985) on Holstein-Friesian cows that had puerperal disorders, a single application of GnRH in the period 10-14 days postpartum, reduced the time interval from parturition to the reappearance of physiological estrus and conception by 43 to 48 days. It should also be noted that cows that were administered GnRH 10-14 days postpartum had 26% to 41% fewer repeated artificial inseminations, i.e. conception was more successful. The author concludes that early postpartum treatments with GnRH improve the fertility of cows, especially in those with puerperal disorders. According to our results, the application of Receptal 10 – 14 days postpartum also led to a faster recovery of ovarian cyclicity. In our research, due to the smaller number of treated cows, the results did not show such improvements, but they indicated that the application of Receptal may restore ovarian cyclicity earlier.

In research by Leslie et al. (1984) after examining the effect of GnRH hormone administred in the period 8-14 days postpartum, in cows that had retained placenta, the authors conclude that there are no significant differences between treated and untreated cows regarding the interval from parturition to the first observed estrus, the interval from parturition to insemination , the interval from parturition to conception and the number of inseminations required to conception. However, for herds in which breeding began earlier in the postpartum period (herds having a mean less than or equal to 80 days from parturition to first service GnRH treatment resulted in a significantly shorter calving to conception interval as compared to control. Moreover, Lee et al. (1983) concluded that after GnRH application the conception rate increased by 15% to 18%, which is probably related to general and reproductive health status.

This conclusion of Lee et al (1983) .agrees with our research in which we observed an increase in conception in cows that were administered Receptal 10., 11., 12., 13. or day 14th postpartum. It should be emphasized once again that due to the smaller number of cows that were included in the research, the number of cows with cyclicity and conception is not statistically significant, but it is noticeable.

CONCLUSIONS

About 30 to 40% of heifers will require veterinary assistance before parturition. The application of GnRH is more effective in restoring ovarian cyclicity when administered on the 13th or 14th day postpartum. Cows receiving GnRH on these days also have a higher chance of conceiving earlier. While GnRH use in the early puerperium positively impacts the restoration of ovarian cyclicity and the timing of conception, the effects are not significant to a large extent.

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AN OVERVIEW OF THE AVAILABLE MEASURES FOR THE CONTROL OF *DROSOPHILA SUZUKII* (DIPTERA, DROSOPHILIDAE)

Dragana BOŠKOVIĆ*, Slavica VUKOVIĆ, Mihaela KAVRAN, Sanja LAZIĆ, Aleksandra ŠUŠNJAR, Jelena EĆIMOVIĆ, Dragana ŠUNJKA

University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia
*Corresponding author: dragana.boskovic@polj.edu.rs

ABSTRACT

The spotted wing drosophila (SWD), *Drosophila suzukii* Matsumura (Diptera: Drosophilidae), is considered a significant invasive polyphagus pest of soft-skinned fruit, including raspberries, strawberries, blackberries, figs, blueberries and cherries. Apart from ripening fruits, *D. suzukii* females lay eggs in numerous wild fruits as well. In the Republic of Serbia, it was detected for the first time during October and November 2014, where it endangers the production of raspberries, one of the most important fruits for the country. Considering a high reproductive rate and short generation time, easy and fast-spreading due to global trade, and a suitable climate with the presence of host plants year-round contribute towards making this pest a serious threat to the reduction of quality and yield of growing fruit. Current control efforts rely mostly on the use of chemical insecticides. In addition to insecticides, sanitary measures and mechanical control are used to control this pest, which is an indispensable and important stage in safe fruit growing. This article provides an overview of the impact of *D. suzukii* on fruit production and establishes available measures and strategies for its control in the Republic of Serbia.

Keywords: *Drosophila suzukii, chemical control, mechanical control, monitoring, traps.*

INTRODUCTION

Drosophila suzukii Matsumura (Diptera: Drosophilidae), spotted wing drosophila (SWD), is a polyphagous invasive pest that affects fruit production of stone and, especially berry fruits. Unlike most other Drosophila flies, which lay eggs in fallen, or rotting fruit, owning to the fact that, they can not penetrate the skin of the fruit, in contrast, the SWD females lay eggs in ripening, intact fruits. SWD is widely distributed in regions from Japan to Pakistan, with temperate climates. Due to the global fresh fruit trade, combined with the cryptic nature of the larvae in fruit, it has gradually spread to other parts of the world (Walsh, 2011). *Drosophila suzukii* has spread to Europe, Asia, Africa, America and Oceania. In North America, the first record of SWD was in 2008 in California. Its distribution in the USA has since

increased significantly (Burrack et al., 2012). The first record in Europe was in Spain during 2007. It then quickly spread to other parts of Europe and soon after, it was reported in other European countries including France, Austria, Germany, Belgium, etc. (Cini et al., 2012). Presence in the region was first recorded in Croatia in 2011 on the traps placed in raspberries, peaches, and grapevine (Milek et al., 2011). In Bosnia and Herzegovina SWD was first found in 2013, in several sites in Herzegovina (Ostojić et al., 2014). On the territory of Serbia (Figure 1), the SWD was first registered in 2014 in four sites (Rasinski, Mačvanski, Raški, and Pčinjski) as well as in Zemun (Belgrade) in sampled raspberries, blackberries, figs and grapes (Toševski et al., 2014). During 2016, in the region of Kraljevo, Užice, Čačak, and Novi Sad first flies were registered and captured in traps. During September of the same year, in 29 regions of Serbia, the presence of flies in traps on various types of fruit was determined at 90 localities (Budić and Janković, 2016). Since 2011, *D. suzukii* is listed on the European and Mediterranean Plant Protection Organization (EPPO) A2 list of quarantine pests.

Figure 1. Distribution of *D. suzukii* on the territory of Serbia in 2014 (Toševski et al., 2014)

Biology and Ecology of *Drosophila suzuki*

In addition to larvae, which cause direct damage by feeding on the fruit pulp, the females also cause damage when laying eggs giving the fact that an oviposition scar is a suitable place for the attack of other pathogens and insects which cause additional damage to the fruit and increase economic loss due to reduced quality (Walsh, 2011). The larvae develop and feed inside the fruit, which increases the sugar content, followed by fruit changing color and softening which reduced the market value. The SWD is a polyphagous pest with a broad host range that can infest many fruit crops, over 80 from 19 different families. It can also infest wild

and ornamental plants, including Honeysuckle (*Lonicera spp.*), wild Brambles (*Rubus spp.*), Mulberry (*Morus rubra*), Elderberry (*Sambucus spp.*), and others (Kenis et al., 2016). It most often infests thin-skinned fruits such as blackberries, raspberries, blueberries, strawberries, figs, cherries, and various types of grapes. It also attacks fruits with harder skin including peaches, plums and apricots but previously damaged. Differences in sensitivity between different fruits, but also the varieties themselves, are influenced by various factors such as soluble sugar content, pH, thickens of the skin and fruit penetration force for puncturing the skin (Rajinder and Stelinski, 2017; Shrader et al., 2018; Walton et al., 2019). The most economic impact was recorded on raspberries, blackberries, strawberries and cherries, where during strong attack loss of yield percentage can go to 80%, even 100%. High reproductive capacity and short generation time, with the possibility of developing up to 13 generations per year contributes to its rapid spread (Tochen et al., 2014). Adults mostly occur in the first half of April, or even earlier (unpublished data), during March. They are most numerous in the period May-June and September-October.

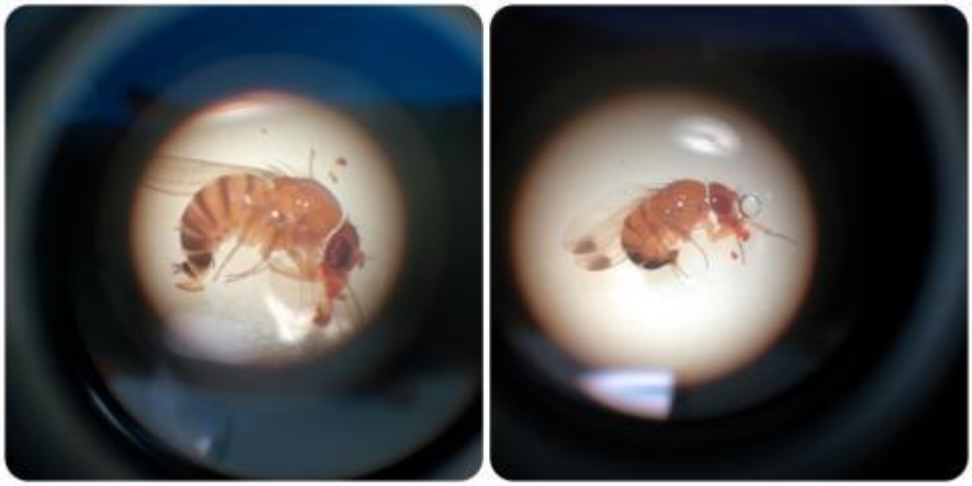

Figure 2: Female (left) and male (right) (Bošković, 2020)

SWD adults are small, 2-4 mm long with characteristic red eyes (Figure 2). Females are usually larger than males. They are mostly confused with *D. melanogaster*, but the SWD adults are larger than the fruit fly. Males have one dark spot on the edge of the both wings, while females do not. Another important male feature is the presence of one row of black combs on the first and also one row on the second tarsal segment. Femalse don't have these these two rows of combs. The females main feature is large serrated ovipositor, which ables them to penetrate the fruit skin is saw-like with serration that are pretty darker then the rest of the ovipositor. The female lay eggs generally from April to November (Mitsui et al., 2010). During their lifetime, female can lay up to 300 eggs. In the same fruit different females can lay eggs (Hauser, 2009; Rajinder and Stelinski, 2017).

The eggs are oval, milky white with two aeropiles at one end (Figure 3). It takes 2 to 72 hours for the larvae to hatch from the egg. Larvae are cylindrical, milky-white with black mouthparts (Figure 3). The complete development take place inside the fruit. Larvae go through three instars before pupation process. It takes from 3-13 days for larvae to mature, depending on the temprature. The larvae are the most harmful because they feed inside the fruit, which leads to its decay. Pupation can take place inside the fruit, or on its surface as well as in the soil. The pupal stage lasts from 4 to 5 days. Pupas are brown (Figure 3), spindle-shaped, with two small finger-like projections at the end (EPPO, 2013; Van Timmeren et al., 2017; Rajinder and Stelinski, 2017).

Figure 3. Eggs (left), larvae (center) and pupa (right) (Bošković, 2022)

SWD favors a moderate climate but it can, as well, survive in a colder environment. The life cycle, from egg to adult, ranges from about 9-10 days at higher temperatures (24-26 °C) (Kanzawa, 1939). SWD overwinter in the stage of adults in the leaf litter that ensures protection from cold conditions. Flies get mobile above 5 °C, and if the average temperature is above 10 °C they start to become active (Hamby et al., 2013; Tochen et al., 2014). The only reliable stage for identification is adult, where the identification of males is even possible just by observation if the dark spots on the wings are visible, while for the identification of females it is necessary to observe them under a certain magnification (Walsh et al., 2011). The dark spots on wings, as well as two sets of black tarsal combs for males and serrated ovipositor for females, make the identification of *D. suzukii* easy, especially on the European continent because no other species of Drosophila, present in Europe have similar morphological features.

Monitoring of Drosophila suzuki

Prosperous agricultural production and prevention of damage caused by this pest require the utilization of fly traps which can be used for mass traping and monitoring. In this way, data collected through traping enables the monitoring of population dynamics and thus ensures timely and effective control of this pest.

Due to the high reproductive rate, short generation time, and fast spreading, the early warning system is of exceptional importance, especially in those regions where its presence has not yet been established. By trapping, it is not possible to

determine the precise population density of *D. suzukii*, due to the fact that traping is affected by various factors such as climate conditions like temperature and precipitation, environmental factors in the site where traps are placed (presence of fruit, is the overwintering habitat nearby, whether are traps installed correctly, is the baitsfresh and properly stored) (Clymans et al., 2019). Sampling by trapping allows only approximate values assessment of population density.

Monitoring and trapping of *D. suzukii* adults in orchards and vineyards can be done using different traps. As a bait, a mixture of yeast, sugar, and water can be used; fruit purees, different types of vinegar, wine, a mixture of ethanol, acetic acid and phenyl ethanol. At the beginning of its distribution on the European continent, there were no specialized traps for catching them, but in the last few years, these kinds of traps can also be found on the European market (Walsh et al., 2011). The traps should be placed no later than one month before the fruit ripening begins, although some individual flies are caught already in March or even in November, i.e. when the temperature is above 10℃ for several days. One of the traps used for mass trapping and monitoring of the SWD is Drosal Pro. Both females and males are caught in this trap, as well as other species of Drosophila sp., while other non-target insects are caught only sporadically. They are very simple to use and can be used repeatedly in all types of orchards. The most commonly used bait is based on a mixture of apple and wine vinegar, which is poured into plastic bottles, representing an improvised trap (Lee et al., 2011). The advantage is the simplicity of application, low price, and easy availability. These traps can be easily made at home from ordinary water bottles (Figure 4). The main disadvantage is reflected in their reduced selectivity because many other non-target or beneficial organisms can be caught as well. This problem can be overcome by reducing the hole size on the bottles, which at the same time affects the reduction of the evaporation of the bait, due to which the bait remains fresh and attractive for a longer period of time. Trap design is very simple. About 6 small holes are made on the upper third of the one-liter plastic water bottles, the smaller the holes, the greater the selectivity. The easiest way to make the holes is by piercing them with a red-hot nail, making sure that the diameter is no more than 5 mm. On the top part of the bottle, cut a larger opening (4x3 cm) through which the smell of the bait can spread. It is necessary to cover the opening with a fine mash in order to prevent other insects from trapping inside. In orchards, the traps are placed along the plot's edges (5-10 m apart one from another) in shaded parts of the crown. The height of traps should be at the same level as fruits (e.g. for raspberries at the height of 30-120 cm; for cherries at a height of 1-2 m) (PIS Vojvodina, 2018). The lure of SWD traps can be increased by alternating taping black and red tape in the lower half of the bottle. The SWD is attracted to the contrast between dark and light colors, such as black/green and red because they mimic the contrast between the leaf surface and the fruit (Basoalto et al., 2013). Intervals of monitoring and replacement of traps should be done at least once a week (Walsh, et al., 2011; EPPO, 2013; Tran et al., 2020).

Figure 4. Improvised traps for trapping SWD (Bošković, 2020)

As the season progresses and different fruits ripe, the same bottles can be switched from one to another crop. A mixture of apple and red wine or wine vinegar in a ratio of 1:1 (150 ml:150 ml) can be used as bait. A few drops of soap liquid should be added with the aim of reducing surface tension (eg dish detergent) in order to ensure submersion of the flies. A mixture of ethanol and acetic acid can also be used as bait, but in field conditions, they proved to be less effective than a mixture of wine and apple cider vinegar (Landolt et al., 2012).

At the beginning of the season, females are looking for a place to feed, which means that fermentation smells from the trap are more attractive to them in that particular time. For oviposition, females are searching for the smell of ripe fruit, which explains the lower number of female flies in traps before harvest compared to the beginning or end of the season, even though the number of females present in the orchard is just as high (Clymans, et al., 2019). In addition to the smell of the fruit, the SWD is also attracted to beta-cyclocitral from the leaves (Max Planck Society, 2015). Visual stimuli, such as the intensity of colors and their contrast also affect this fly, which explains the recommendation for control not to be before the coloration of the fruit begins (Walton et al., 2019). Females prefer fruits with a higher pH value, while high acidity repels them. They are also attracted by the high sugar content because larvae develop much faster in such fruit (Wang et al., 2019).

Preventive measures for the control of *Drosophila suzuki*

It is very important to know the pest biology, i.e. the way it overwinters, the preference in choosing fruit for oviposition, spatial and temporal distribution (when and where they were first recorded; when the first adults were observed; the number of flies captured in the traps; the degree of last year's attack, climate conditions, etc.) in order to assess the impact on the yield and to manage right the control plan given the above stated, in a timely manner (Cini et al., 2012; Tonnang et al., 2017). It would be optimal to implement all available preventive measures (mechanical and agrotechnical measures) before applying chemical control, in

order to reduce economic losses and pesticide application. Keeping hygiene, in and around the crop, are very important preventive measures when fighting against this pest, which also includes weed control in these areas. Special tendance should be aimed at the control of wild elderberry (*Sambucus nigra* L.), blackberries (*Rubus fruticosus* L.), strawberries (*Fragaria vesca* L.), and black nightshade (*Solanum nigrum* L.). Hygiene within the orchard refers to the removal of rotten, overripe, and infected fruit that can be a food source or a potential breeding site. Such fruits must be destroyed by burying, solarizing, chemical treatment, or physically by placing them in plastic bags that need to be left in the sun for a few days since larvae are very sensitive to high temperatures. Also, attention should be paid to maintaining the hygiene of all agricultural machinery, tools, and other equipment used during the year. Covering the orchard with insect nets with a diameter of 0.98 mm also gives excellent results. Tillage is recommended in order to kill overwintering forms. Preference should be given to varieties with a harder skin of the fruit and traps should be set for regular mass hunting.

Chemical control of *Drosophila suzuki*

Currently, the control strategy of *D. suzukii* heavily relies on the application of insecticides. Taking into account that the greatest damage appears right before the harvest, chemical control is not recommended due to the high risk of a residues in the fruits. Also, there is a danger for the insect resistance development, as well as, manifestation of pesticide side effects on pollinators and other beneficial organisms (Cini et al., 2012). In Europe, insecticides from the chemical class of pyrethroids, organophosphates, spinosyns, and neonicotinoids are mostly used to control SWD (Shaw et al., 2019). Currently, in the Republic of Serbia, for this purpos, three insecticides are registered (Table 1).

The insecticide based on deltamethrin as an active ingredient, which shows contact and digestive effect, was the first registered. However, the limitation of its application is the prohibition on its use during pollinator flight, as well as the fact that it must be adapted to those regions where resistance to deltamethrin or another pyrethroid has not been recorded. Since 2021, two more active ingredients have been registered. The first, which is based on spinosad, for the used in strawberry, raspberry, blackberry, blueberry and cherries plantations, and the second based on spinetoram for the use in raspberry, blueberry, strawberry, cherries and currant crops (Petrović i Sekulić, 2023). It has already been recorded in the USA and Greece that the SWD can develop resistance to these two insecticides (Van Timmeren et al., 2019; Disi and Sial, 2021).

Table 1. Registered insecticides in Serbia for control of the SWD (Petrović and Sekulić, 2023)

Insecticide	Fruit	Application rate	Application time	Max. number of app.	PHI* (days)
Deltamethrin (EW; 15 g/l a.i./l)	Sour cherry	0,5-0,7 l/ha	At the beginning of fruit ripening	1	7
	Strawberry	0,5-0,7 l/ha		2	3
	Raspberry				14
	Blueberry	0,5 l/ha			7
	Grapevine	0,5-0,7 l/ha			14
Spinosad (SC; 480 a.i. g/l)	Blueberry	0,1-0,2 l/ha	Beginning of ripening or fruit colouration (81-85 BBCH)	2	3
Spinosad (SC; 240 a.i. g/l)	Blueberry	0,1-0,2 l/ha	Beginning of ripening or fruit colouration (81-85 BBCH)	2	3
	Strawberry	0,3 l/ha			1
	Raspberry	0,4 ml/ha			3
	Blackberry				3
	Sweet/sour cherry		Beginning of fruit colouration (59-85 BBCH)	1	7
Spinetoram (SC; 25 a.i. g/kg)	Raspberry	2,4 l/ha	First true leaf, until second harvest: most fruits are colored (11-89 BBCH)	1	7
	Blueberry			1	7
	Currants			1	7
	Strawberry	2 l/ha		1	7
Spinetoram (WG; 250 a.i. g/kg)	Sweet/sour cherry	0,3 kg/ha	At the beginning of larvae hatching	1	7

*PHI – pre-harvest interval

With the aim of reducing the use of chemicals to control this pest, an arsenal of biological control measures is emerging, like the employment of biological control which is based on the use of natural enemies (parasitoids, predators, parasites, pathogens, mycotoxins, antagonists or competitors) (Vuković i Šunjka, 2021; Šunjka and Mechora, 2022). Besides this, an emerging topic in the field of SWD control are bioinsecticides based on essential oils as biologically active agents. These bioinsecticides have the potential to play a significant role in organic and integrated pest management approaches, thereby reducing the need for chemical insecticides (Bošković et al., 2023).

CONCLUSION

Large economic damages and the rapid spread of the invasive pest *D. suzukii* represent a challenge for fruit production in Europe. Effective control of *D. suzukii* in agricultural production requires major efforts at the local and global level. For the successful control of SWD, it is necessary to follow the instructions of the reporting services, as well as to monitor own catch in traps, so that the optimal treatment period can be reached on time. It is necessary to apply all available preventive measures, which include agrotechnical and mechanical, to reduce the spread and infestation, which can significantly reduce the number of harmful organisms. Pay special attention to sanitary measures, which include maintaining the hygiene of fields, non-agricultural areas, tools, machines, crates and other tools that come into contact with fruit. When choosing varieties, give preference to more resistant or tolerant varieties and healthy planting material. Infected or overripe fruits must be destroyed regularly and never be used for composting. Installing insect netting with small openings also provides good protection. Traps should be used for mass hunting and monitoring, and chemical control should be used only under justified conditions.

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OPERATIONALIZATION OF ICT FOR ENHANCING AGRITOURISM POTENTIALS OF ANIMAL HUSBANDRY PRACTICES IN INTEGRATED FARMS' IN NIGERIA

Olawuyi Olakunle S.[1], Alabi R. A.[2], Robert A. B.C.[3]

[1]Tourism Studies, Osun State University, Nigeria
[2]Department of Archaeology, University of Ibadan, Nigeria
[3]Department of Computer Science, University of Ibadan, Nigeria.
*Corresponding author: olakunle.olawuyi@uniosun.edu.ng

ABSTRACT

Information communication technology is being engaged by people for various reasons. There are different types of ICT that are used for meeting different needs. Agritourism essentially implies time bound leisure trips to farms or ex-farm houses. Agritourism in Nigeria is essentially in its potential stage as many farmers and investors are not engaging it yet. Thus, it is pertinent to examine how these agritourism potentials can be turned into full blown assets with available technologies. Data were elicited from farmers into integrated farming systems in Ibadan, Nigeria, with the aid of questionnaire and analysed both descriptively and inferentially. The result revealed that most of the farmers are aware of ICT facilities and use them for different agricultural engagements. The tourism potentials of the integrated farms based on the different engagements of the farmers that can enthuse agritourists like feed composition and milling, livestock pen, vaccination and medication services amongst others were highlighted. The result of the study further revealed that ICT components (radio, television and the internet) have significant relationship with the following indicators of animal husbandry; feed composition and milling, breeding of animals, sight of animals, livestock pens, animal slaughtering and animal dressing. However, ICT has the largest effect on animal slaughtering.

Keywords: *Agritourism potentials, animal husbandry, ICT.*

INTRODUCTION

Information Communication Technology (ICT) can be broadly categorized into Information Systems and Information Technology. Recently, ICT became a critical tool for most organizations, likewise, businesses of which education is part (Bingimlas, 2009). ICT devices aids the facilitation of farming activities and they include gadgets such as laptops, mobile gadgets application software and so on. Boell and Cecez-Kecmanovic (2015) examined four views in defining ICT and this has basis on major sections reiterated through specific defining characteristics: (a)

technology based section, which is inclusive of the process, storing and transforming of data; (b) social categories, reiterating that information systems are intrinsic in social methods; (c) social technical categories, with arguments that information system is inclusive of both societal and technology constituents that are interwoven; and (d) process categories – the conceptualization of information system with regards to the performance and support procedures and methods.

Agritourism involves welcoming visitors to farms for educational, leisure or business purposes. The concept of agritourism from the farmers perspective is essentially the synergy between the agricultural enterprises cum operations and tourism, in a bid to expand the farmers revenue generating base. Grillini *et al.*, (2022) asserted that visitors that make payments to sleep or/and eat on a farmland might aid the stabilization of a traditionally run farm via the creation of a connection between various business engagements, precisely, agriculture and tourism. From the perspective of tourist, the concept of agritourism involves visitors travelling to farm lands, for leisure, business, conferences and events. Agritourism can simply be conceptualized as different agriculture-based tourist engagements domiciled in rural areas, precisely, based on pleasurable/educational experiences (Gil *et al.*, 2013). Xiaowen *et al.*, (2022) opined that agritourism is a mix of agricultural practice with tourism premised on farm assets. It may involve business transactions by the famers and his/her customers that will necessitate the customer to spend considerable amount of time on the farm. It may also involve active participation of visitors in farming activities in a bid to lend a helping hand to the farmer. Based on reviewed literature, it is evident that a gap exists vis-à-vis operationalizing ICT to enhance agritourism potentials of animal husbandry activities in integrated farms. This study thus examined the operationalization of ICT in enhancing agritourism potentials of animal husbandry activities in integrated farms' in Nigeria.

Concept of Agritourism

According to Tew and Barbieri (2012), academics have found it difficult to create a grading scheme that takes into account both the traits as well as the general concept of agritourism. So, different scholars have come up with different perceptions on agritourism but the indices that establish the nexus between these various perceptions are agribusiness, farm activities (direct or indirect) and leisure as shown in the figure below.

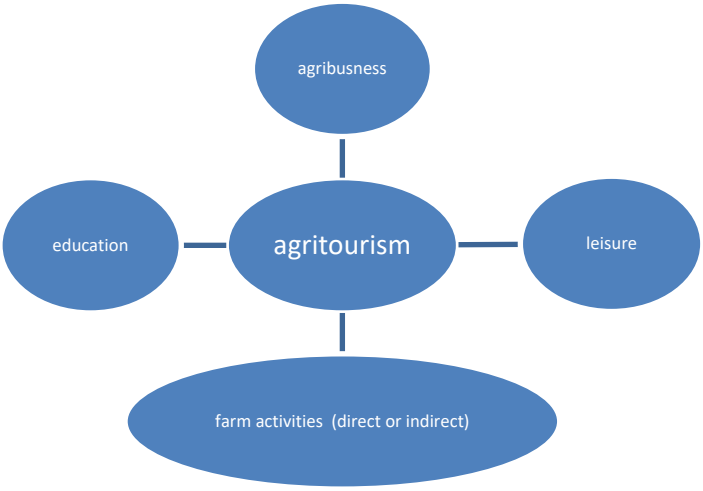

Figure 1. Various indices of Agritourism
Source: Tew and Barbieri (2012)

With respect to the above, agritourism trip is oftentimes underpinned by one or more farming engagements. Therefore, agritourism could be understood from the prism of specific farming activity that an agritourist engages. Karampela et al., (2016) noted that the product of agritourism services could be offered usually on the basis of small packages of agritourism experience and not necessarily from the same enterprise. Thus, an agritourist may essentially visit a farm for a specific agritourism product rather than because of all the agritourism products present in such farm.

Claudia *et al.* (2013:40) explain the inconsistencies in the various defining concepts of agritourism about three concerns that can be discovered with in literature, and they are highlighted below:

(1) the form of setting (for instance agricultural land, farm environment found anywhere);

(2) authentic nature of agricultural land's facilities/experiences; likewise,

(3) forms of activity engaged (for instance, lodging, education).

The settings of a typical agritourism destination have various indices that range from size of the farm, the social and financial settings for agricultural land, farms' mechanization, the farmers' experiences, how well the farm has been synergized with tourism and the likes. According to Sofia *et al.,* (2016) there are two issues that are of importance with regards to the social economic settings of agritourism and they are:

(a) the size of operations of the businesses;

(b) and associated nodes of the businesses on various categories, likewise the size of additional worth of activities earned on an indigenous basis.

Phillip *et al.,* (2010) observed from an academic standpoint, that sorting discrepancies inclusive of attempts to establish a general description of agritourism can assist in producing a better homogeneous study area, that allows for better

focused inputs in the long run. These various attempts at defining and explaining agritourism reveals that agritourism is a unique concept that various scholars want to profoundly understand and associate their research with. There are however, certain components that essentially serve as the buildup of Agritourism. These components include

the Farm,

on farm accommodation or nearby lodging facilities, relaxation huts/sheds, location for learning about the overview of the farm and for questions and answers

and parking spaces.

Agritourism has immense advantage to country-sides as well as stakeholders involved in leisure trips to farm settlements and locations. Fagioli *et al.,* (2014:164) noted that agritourism serves as a catalyst promoting vital growth of tourism throughout country sides and encourages growth of rural areas, enabling the farmer's family to augment agricultural revenue through money from tourism-related operations. It has not only served as a driver for developing touristic activities in the country side, it has particularly served the purpose of driving enhancement and restructuring of the country sides. Rogerson and Rogerson (2014) noted that on the outer side of South Africa's major cities, tourism takes an equal important significance in subsidiary cities' attempts to diversify their economies and in the post-productivist rural areas that has accompanied restructuring of rural areas. Agritourism helps in generally developing agricultural activities such that it is done in a way that would be appealing and informative to the visitors.

To the farmer, the business aspect of agritourism is sacrosanct, so, the farmer packages his/her agricultural operation/venture in such a way that leaves long impressions on tourist minds. In this sense, agritourism has the potential to serve as a stimulus for boosting the value of such relevant industry to the nation's finances, that may be expanded by giving people the chance to live at or explore farmlands to take part in the gathering or harvests of farm produces (Ahmed and Jahan, 2013). Meanwhile, to the tourists the leisure and knowledge gained from agritourism is sacrosanct, which is why some of the tourists visit the farms with their recording or writing materials while some visit the farm with a mind of relaxation. So, when tourists that are naturally inclined to nature and rural environment embark on tourism to farm(s), they are being availed the opportunity to experience agricultural activities, both on-farm and off-farm operations, as the case may be.

It is established that agritourism is essentially leisure trip to farms or a site with traces of agricultural activities from the past, for a specific period of time. Vaugeois *et al.,* (2017) noted that agritourism events might be inclusive of the following:

(i) Exhibition of heritages of agriculture on agricultural land;
(ii) a visit to agricultural land, a lesson or exhibition across every or some of the agricultural operations carried out there, as well as any task related to any of the activities;

(iii) a compromise of the farmlands as a result of riding cart, sleigh and tractor on farmlands;
(iv) Events like exhibitions, cattle drives, and petting zoos which advertise or promote livestock on the farm, regardless of if the event also features livestock from different farmlands or otherwise;
(v) Trial activities for dos carried out on farmlands;
(vi) harvesting celebrations as well as other season-based activities carried out on farms to advertise or promote agricultural produce made on farmlands;
(vii) Maze of corns done via maize plantation on the farmlands.

Agritourism can be considered from its connection to the economy, society as well as the environments, which are major sustainability constituents (Muresan *et al.*, 2016). Similarly, Fanelli and Romagnoli (2020) noted that agricultural facilities with an instructive farm can exhibit substantial relevance in rural sustainable development, inclusive of cogent implications on the surrounding, farm heritage, culinary and the development of the economy. It is pertinent to note that sustainability in agritourism can be in two categories; it could be sustainability of the agritourism venture and it could be sustainability of certain quarters like cultural, social, environmental and economic, consequent upon the agritourism venture in a particular destination. Sustainability of the agritourism venture is all about ensuring that the venture does not fail or close down abruptly. This is categorically possible as long as the tourists are ready to pay for the agritourism product, so that the revenue accrued from such purchase will be channeled to effective management of the agritourism venture.

Concept of ICT

Audu (2022) Information Communication Technology (ICT) devices generally revolves around embracing a lot of media that are inclusive of telephones, television, videos, telex, voice information system, Global System for Mobile (GSM) as well as faxes and the ones that require usage of PCs that has contemporary technology which facilitates communicating, as well as transmitting information via electronical avenues that ranges from radios, televisions, telephones as well as the internet. Synowiec (2021) noted that ICT is usually engaged synonymously for information technologies (IT), whereas ICTs is a generic concept which reiterates roles of unified technological innovations as well as a fusion of telecommunication (phone line as well as wireless connection), computer, middlewares, software applications, storages as well as audiovisual system which give rooms for a user to establish and gain connection to information, as well as storage, transmission as well as edition. On a contrary note, IT is a component of ICT, and telecommunication, media broadcast, various forms of audio and video procedures, transmitting, as well as network functionalities of managing and monitoring (Kuzior and Lobanova 2020).

Agwu et al., (2008) noted that ICTs are of rarefied characteristics which make available privileges for harnessing them through diverse means which have clear difference from how orthodox media had been operationalized in terms of

developments. It basically enhances the capability of searching for information as well increasing available quantitative information, eventually ameliorating uncertainties, as well as improving markets involvement. Audrey and Charlotte (2016) noted that ICT is good and service with heterogeneity engaged in production, processing, distribution as well as transformation of information. ICT could have a multiplier effect of connecting different persons together, improvement of supply chain, facilitating business transaction, at the same time ensuring that the dynamism of prices is well managed.

Ranjita and Manju (2020) noted that ICT infuses different gadgets, computers or software applications which enable sharing of information or gathering via interactions as well as transfers. It could be used in form of advising a farmer, empowering the adult female gender, markets information, assessing the quality of soils as well as general development of the hinterland. William and Matern (2018) ICT as well as the Internet have generally been the main indicators that drive economic successes, premised on the fact that it aids in producing as well as disseminating knowledge in sporadic as well as effective means. Rahman and Bashir (2020) noted that ICT could be perceived as efficient communication means, precisely, when time and distance constitute major challenges.

ICT and agricultural practices

William and Matern (2018) noted that ICTs engagement for agricultural practices is quite massive, premised on the fact that it could be engaged in monitoring threshold of pests in managing pests in an integrated form, provision of pertinent as well as contemporary news, likewise farming service, agri-biodiversity of maps for many crop systems, forecast disaster as well as prediction of outputs. Consolata (2015) noted that ICT could serve as efficient way to disseminate to a community, a plethora of pertinent market information, technologies, price, achieved experience, credit facility, governmental service and policy, climate, crops, livestocks as well as preservation of natural resources.

Audu (2022) submits that higher efficiency with regards to time, costs, service and product qualities could be achieved in agricultural engagements via the usage of ICT. Audrey and Charlotte (2016) submitted that via contrast, ICT does not only have potentials of enhancing productivities in agriculture in Africa, they could likewise enhance productivity via the advancement of a “green” agricultural engagement in Africa. Adekunmi and Awoyemi (2017) noted that via the usage of ICT, a farmer could get in touch and obtain information from another farmer, researcher as well as scientist in different parts of the globe with ease. Owotogbe et al., (2019) noted that smart phones as well as similar technologies are regarded as being able to attract precise solutions, basically so as to aid farmers in gaining access to germane information. Ranjitha and Manthu (2020) noted that the role ICTs play in agricultural engagements are inclusive of agricultural activities based on sustainability, improvement of consumers access, managing risks associated with disasters, agricultural extensions and empowering old female as well as the youths.

Theoretical Framework

Social Cognitive Theory

Social cognitive theory was created by Bnadura in the Mid 1970's. This theory has psychological inclinations that reveal the means through which people within social systems effect different human procedures, that includes the procurement and engagement of data and knowledge. The essence of social cognitive theory is learning of new things, ideas and concepts. It basically aids people to quickly conform with or adopt new norms and ideas in the society. It is all about the acquisition of new knowledge at specific point in time. Jenkins, Hall, and Raeside (2018) opined that in social cognitive theory the profound understanding of novel skill and knowledge are of more important interest over the output or goal of the educational procedures. This theory is specifically important for the adoption and adaptation of ICTs because, from time to time, new ones with their precise peculiarities are created and hence, they must be learnt and understood before they could be explored.

MATERIAL AND METHODS

Description of study area

The study area that captured the integrated farms are the Local Government Areas with vast rural areas that have farm settlements or a high concentration of farmers. This is because farmers into integrated farming systems were chosen from these Local Government Areas. The Local Government Areas are as follow; 1) Akinyele Local Government area, 2) Ido Local Government area, 3) Lagelu Local Government area, and 4) Egbeda Local Government area.

It is believed that Ido Local Government Area is the biggest Local Government Area (in terms of land area) in the city of Ibadan, because, the census population (National Population Commission, 2006) revealed that Ido has a population of 104,261 and it also has a land area of 986 km^2. Akinyele Local Government Area is situated between latitude 7^o 29' and 7^o 40' N while its longitude ranges from 3^o 45' to 4^o 04' E. It is largely agrarian and residential. Egbeda town is the current political headquarter of Egbeda Local Government Area (LGA) of Oyo State. The town is located on latitude 7^0 21'-8^0N and longitude 4^0 02' – 4^0 28'E with a total land area of approximately 191km^2. Akinbile and Ikechukwu (2017) submit that Egbeda Local Government Area currently has four urban and seven rural wards. Lagelu Local Government area has a total land area of about 355.50 hectares and falls between latitude 7^o20' and 7^o50' East of the Greenwich Meridian. This local Government area is divided into Lalupon, Olorunda, Igbo-Elerin and Iyana Offa. The Local Government Areas are captured in the figure below.

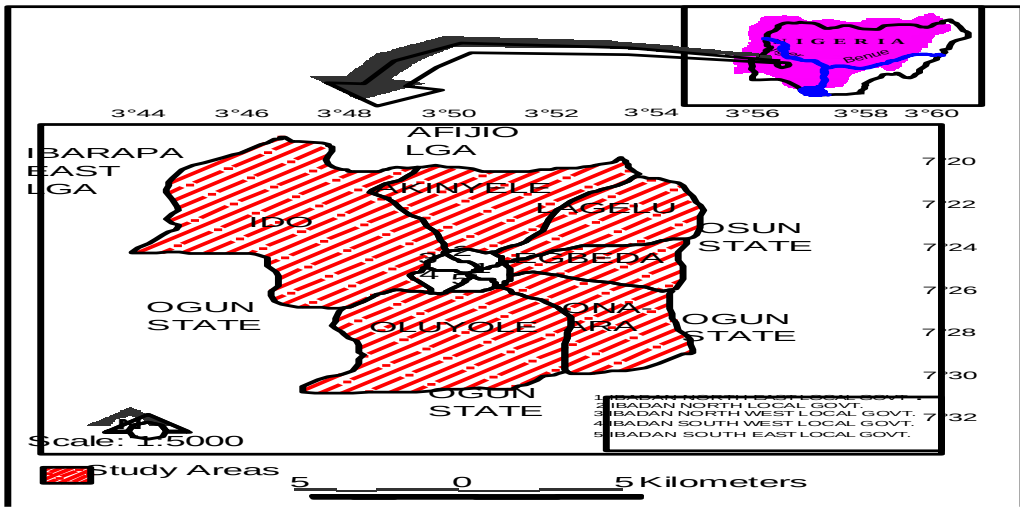

Figure 2. The five (5) Local Government Areas in the Agricultural Zone of Ibadan

Sampling procedure

For this study all the farms that operate integrated farming system within these Local Government areas were visited and questionnaires were administered to them. Hence, no sampling frame was adopted for the quantitative aspect of this study. A total of two hundred and five (205) farmers that are essentially into integrated farming system were sampled. All the integrated farms in the study area were completely enumerated. Meanwhile, from these farmers, ten questionnaires were returned not filled while seven where badly filled, hence, one hundred and eighty-eight (188) valid data were retrieved.

Reliability of the Research Instrument

Cronbach's alpha was engaged in determining reliability of the research instrument (questionnaire). Reliability of an instrument essentially depicts the internal consistency of such instrument. Internal consistency basically reveals the appropriateness of specific indicators engaged as components of the research instrument. Since, reliability is expressed in numerical terms as a coefficient, John (2015) opined that a coefficient index that is high implies high reliability that has less error, while, a correlation coefficient that is low implies low reliability with a lot of errors.

Table 1. Reliability Test for the Research Instrument

Cronbach's alpha	Number of items
0.823	12

*Source: Author's field Survey (2020)

It is evident from the table above that the reliability index for the questionnaire is 0.823. This reliability index is high and it depicts a high internal consistency and the fitness of the questionnaire to elicit appropriate data.

RESULTS AND DISCUSSION

It is evident from the table above that one hundred and seventy one (91%) of the respondents have heard of the term ICT and seventeen (9%) of the respondents have never heard of the term ICT. This simply means that most of the respondents have at one point or the other heard of the term ICT. It is pertinent. It was pertinent to inquire of the awareness of ICT by the respondents because most of the respondents are settlers in the farm settlements located in the rural and underdeveloped areas. It is however notable that most of these farm settlers had either retired from businesses and companies in the cities or they have their families in the cities, thus, ICT is trite to them. Chowhan and Ghosh (2020) noted that the extent at which mobile phones have penetrated the hinterlands has led to enhanced significant engagement of ICT in farming practices in Bangladesh.

Table 2. ICT components

Valid	Frequency	Percentage
Have you ever heard of the term "ICT'		
Yes	171	91.0
No	17	9.0
The components of ICT that you are aware of?		
Radio	3	1.8
Television	7	3.7
Internet	50	26.6
None of the above	16	8.5
All of the above	112	59.5
Total	188	100

*Source: Author's survey (2020)

The table also shows that three (1.8%) of the respondents noted that radio is a component of ICT, seven (3.7%) noted that television is a component of ICT, fifty (26.6%) noted that internet is a component of ICT, sixteen (8.5%) noted that none of the above is a component of ICT while one hundred and twenty one (59.5%) noted that all of the above are components of ICT. It is lucid that most of the respondents understand the components of ICT, which is why "all of the above" option has the highest percentage. The knowledge of old ICT components such as radios, print media, as well as television became increasingly common in the midst of farmers when compared with contemporary ICT components, for instance internet, cable television, social media (Ebisike et al., 2021). The engagement of

ICT components gives room for farmers to benefit via better earnings, during hike in the cost of food prices, likewise, management of farms on a sustainable basis. Farmers can use ICT for least important issues about their farming businesses and operations under the term e-agriculture. E-agriculture, which is a growing concept in terms of the innovativeness of ICT, is targeted at boosting the enhancement of agriculture and the hinterland via enhanced information and communication systems (LaiSolarin *et al.*, 2022).

Tourism Potentials of Animal Husbandry

It is obvious from the above that 59.0% of respondents strongly agreed and 34.6% agreed that breeding of livestock is a tourism potential. 43.6% strongly agreed and 50.5% agreed that feeding of livestock is a tourism potential. 41.5% strongly agreed and 51.1% agreed that sight of animals is a tourism potential. 43.6% strongly agreed and 50.5% agreed that farm animal product such as cheese is a tourism potential. 35.1% strongly agreed and 61.2% agreed that livestock vaccination and medication are tourism potentials.

Table 3. Tourism Potentials of Animal Husbandry

Question items	SA	A	D	SD	Mean	SD	Rank
Breeding of animals	111 (59.0%)	65 (34.6%)	12 (6.4%)	-	1.47	0.62	9th
Feeding of animals	82 (43.6%)	95 (50.5%)	11 (5.9%)	-	1.62	0.58	7th
Sight of animals	78 (41.5%)	96 (51.1%)	14 (7.4%)	-	1.67	0.63	5th
Farm animal products such as cheese	82 (43.6%)	95 (50.5%)	11 (5.9%)	-	1.62	0.59	7th
Vaccination and medication services	66 (35.1%)	115 (61.2%)	7 (3.7%)	-	1.69	0.54	4th
Livestock feed composition and milling	70 (37.2%)	100 (53.2%)	18 (9.6%)	-	1.72	0.63	2nd
Livestock pen and houses	68 (26.2%)	108 (67.4%)	12 (6.4%)	-	1.70	0.58	3rd
Veterinary care of animals	96 (51.1%)	84 (44.7%)	8 (4.2%)	-	1.54	0.59	8th
Slaughtering of livestock	68 (36.2%)	95 (50.5%)	25 (13.3%)	-	1.78	0.68	1st
Animal dressing	84 (44.7%)	91 (48.4%)	13 (6.9%)	-	1.63	0.63	6th
Summary					16.44	6.07	

Source: Author's survey (2020)

37.2% strongly agreed and 53.2% agreed that feed composition and milling is a tourism potential. 36.2% strongly agreed and 67.4% agreed that livestock pens and houses are tourism potentials. 51.1% strongly agreed and 44.7% agreed that veterinary care of animal is a tourism potential. 36.2% strongly agreed and 50.5% agreed that livestock slaughtering is a tourism potential. Lastly, 44.7% strongly

agreed and 48.4% agreed that animal dressing is a tourism potential. It is clear that all of the respondents strongly agreed, agreed and disagreed on each of the indicators in the table above, however, most of the respondents either strongly agreed or agreed. The missing systems, are essentially, for the indicators that the respondents chose no available option for, this might be either as a result of the fact that they are either undecided or not sure of their responses.

Meanwhile, the result reveal that the mean value of above is 16.44. Notably, predictors of tourism potentials of livestock farms were subjected to critical rating by their mean values. Likewise, the significance of the mean scores for the indicators above simply implies that the lower the mean score the lower the perception of the respondents about the variable that captures all the indicators and vice-versa. This is so because each of the indicators is meant to help properly justify the set variable. In that light, it is of utmost importance to measure each of these indicators in a bid to decipher their significant implications for the research.

Therefore, no statistical difference is evident amongst the predictors, their mean values as well as standard errors were used in rating them; animal slaughtering (1.78±0.68), Feed composition and milling (1.72±0.63), Livestock pen and houses (1.70±0.58), Vaccination and medication services (1.69±0.54), Sight of animals (1.67±0.63), Animal dressing (1.63±0.63), Feeding of animals (1.62±0.58), Farm animal products such as cheese (1.62±0.59), Veterinary care of animals (1.54±0.59) and Breeding of animals (1.47±0.62). This simply implies that tourism potentials of animal husbandry in an ascending order according to the farmers can be rated as follow; breeding of animals, veterinary care of animals, farm animal products such as cheese, feeding of animal, animal dressing, sight of animals, vaccination and medication, livestock pen and houses, feed composition and milling and animal slaughtering.

It is notable that there was no statistically significant difference amongst predictors of animal husbandry's activities, thus, mean scores as well as standard errors were used in rating them in descending order based on the following;

1) animal slaughtering (1.78±0.68),
2) Feed composition and milling (1.72±0.63),
3) Livestock pen and houses (1.70±0.58),
4) Vaccination and medication services (1.69±0.54),
5) Sight of animals (1.67±0.63),
6) Animal dressing (1.63±0.63),
7) Feeding of animals (1.62±0.58),
8) Farm animal products such as cheese (1.62±0.59),
9) Veterinary care of animals (1.54±0.59) and
10) Breeding of animals (1.47±0.62).

In the light of the above, it is evident that different operations of animal husbandry is capable of attracting visitors to farms. Winter (2020) stated that visitors have the prerogative of travelling to sight and engage vis-à-vis petting, swimming with, riding with and taking personal photographs with dolphins, tigers and different animals with charisma and animals at the edge of extinction. There are various

attractive phases in the tourism sector; for instance, tourists can participate in the observation of animals in the safaris, tourists can meet and cuddle with cats in cafes, tourists can volunteer to work with goats in farmlands and danger tourism that involves getting closer to fearful predating animals (Essien, Lindsjo and Berg, 2020).

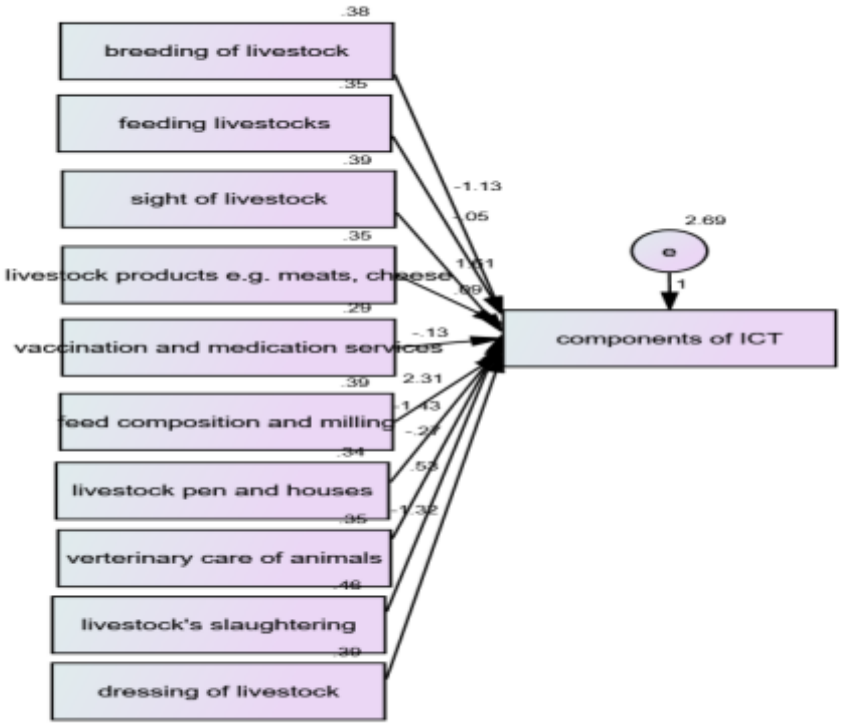

Figure 3: Path analysis

The above path diagram shows a regression analysis between ICT components and indicators of animal husbandry in integrated farms. The chi-square value is 1779.43, P-value of 0.000 and NFI of 0.226. It shows that ICT components have significant relationship with the following indicators of animal husbandry; feed composition and milling, breeding of animals, sight of animals, livestock pens, animal slaughtering and animal dressing. With respect to engaging indices of standardized estimates in deciphering the effects of the endogenous variable on the exogenous variables. It is evident that animal slaughtering has a large effect (S.E at 0.771), while feed composition and milling, breeding of animals, sight of animals, livestock pens and animal dressing have medium effects. This implies that ICT can be used to enhance more of slaughtering of livestock than other animal husbandry

activities in an integrated farm. Some of the integrated farms have sections where they slaughter, dress and package livestock, so that they may be directly sold off to consumers. Meanwhile, it is notable that with respect to the ranking of the potentials of animal husbandry that is evident in table 2, slaughtering of livestock animals as a tourism potential has the highest rank. Thus, it is no coincidence that ICT has the largest effect on vis-à-vis enhancing it as an agritourism potential.

ICT can showcase these agritourism potentials to prospective agritourist in other parts of the Country and the World. It is common knowledge that ICT has been engaged for tourism and agriculture at various levels. Anand (2013) noted that ICT is capable of empowering customers in identifying, customizing as well as purchasing tourism product and supporting the efforts of globalizing the business sector via the provision of facilities to develop, manage and distribute organizational products to the World. Khan and Hossain (2018) noted that E-tourism gives regulation to organizational competition via seizing intranets advantages in rescheduling internally driven procedures, extranets is for enhancing business dealings with reliable shareholders as well as the internet to interact with all shareholders and customers. Oke (2023) noted that essentially, tourism businesses may not be seemingly engaged if ITC is not engaged, right now, as a result of the extent of global creativity, ICT's engagement exceeds mere information dissemination, it has created privileges for business entities to connect with various consumers with the products information. ICT give room for the connection between consumers and management as well as control of supply chains to be synergized to one major source capable of facilitating various procedures- selecting products, making orders, fulfilments, tracks, payments and reports means to be engaged via single easy to use tools. Vujovic (2019) noted that summarily, ICT in the light of money and time is expected to significantly add to the reduction of cost, limiting process time as well as maximization of profit, at the same time adding to enhanced valuable services with reduced financial input and with real time from the trajectory of demand.

Thus, it is expected that ICT being able to enhance agritourism potential should be doable and realistic. ICT could also make agribusiness inclinations of agritourism seamless. This is premised on the fact that some of the agritourist may essentially be at the agritourism farm for business transactions. Olawuyi (2022) noted that among other types of individual(s) that can be referred to as agritourist(s), an agritourist is an individual that has travelled to a farm to transact agricultural business. However, these business transactions have elements of leisure because the agritourist must have temporarily disengaged from their workstations, offices or shops ab-initio. ICT is capable of transforming an agritourism destination into a heritage for the farm owner. ICT tools makes digitization of agritourism activities and components seamless. ICT makes it easy to pass the modus operandi of the agritourism business to the incoming generation and it further serves as a repository where agritourism information can be kept on a sustainable basis. Behera *et al.*, (2015) noted that e-agriculture adds good worth to farm owner's life as well as consumers premised on sustainable development via e-governance,

weblinks for managing knowledge, virtual kiosks as well as regular servicing locations in the categories of local communities. It is lucid that both the farm owners and the prospective customers can utilize ICT for their own benefit. Meanwhile, ICT transforming an agritourism destination into a heritage resource, makes sustainability of the agritourism venture quite easy, because the knowledge adopted in the first place to preserve the business and ensure profitability can be easily accessible by new generation. In the same vein, digitization can be employed to view sustainable practices used for agritourism business operationalized on different regions of the globe and these operations whose adoption is essentially premised in local agritourism business. With respect to the fact that most of the farmers noted that their awareness and usage of internet as a component of ICT, internet can be robustly engaged to enhance agritourism potentials of the selected integrated farms. For instance, Javeed et al., (2020) submitted that an electronic platform to transmit information to farm experts vis-à-vis broad issues that are connect to agricultural engagements, for instance, cultivating crops, forecasting of weather, making available farming input, financial companies connected to farming and agribusiness is called iKisan iKisan. Olawuyi *et al.,* (2017) noted that contacting agents of tourism destination by potentials customers becomes easy as messages can be sent to them through messaging platforms on their internet portal. In the same vein a similar e-platform can be created in enhancing the agritourism potentials of animal husbandry activities of the selected integrated farms.

CONCLUSION

On the basis of ranking of the indicators, the findings revealed that animal slaughtering is the highest agritourism potentials of the selected integrated farms. Similarly, the results of the study reveal that ICT components (radio, television and the internet) have significant relationship with the following indicators of animal husbandry; feed composition and milling, breeding of animals, sight of animals, livestock pens, animal slaughtering and animal dressing. However, it has the largest effect on animal slaughtering.

The submission that ICT can easily enhance agritourism potentials of integrated farms is underpinned by the social cognitive theory that was adopted for this research. It basically underpins farmers awareness of ICT, which underscores their acceptability of ICT. While conceptualizing the knowledge of a farmer on ICTs agriculture's creativity's engagement, it can be averred that acceptability of users, integrating and engaging of recent technologies happens and get enhanced over a period as a result of the impacts of various interconnected matter (Mng'ong'ose and Victor, 2018). The social cognitive abilities of farmers about these ICT components can aid farmers to better showcase/advertise these agritourism potentials to people in different parts of the world, aid farmers in better packaging these potentials and also aid farmers to carry out seamless agritourism businesses.

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INVESTIGATING THE OPTIMUM DENSITY OF PLANTATION OF NOBLE *SACCHARUM OFFICINARUM* CANES UNDER CERTIFIED ORGANIC CONTEXT USING LEAF AREA INDEX

Marotea VITRAC[1*], Taivini TEAI[1], Ines SHILI-TOUZI[2], Laurent MAUNAS[3], François-Régis GOEBEL[4]

[1]Research mixt unity about Insular ecosystems in Oceania (UMR 241 EIO), University of French Polynesia (UPF), Punaauia, French Polynesia
[2]Agro development engineer school (ISTOM), Angers, France
[3]Polynesian development of agriculture administration (DAG), Pirae, French Polynesia
[4]Agroecology and sustainable Intensification of annual crops (UR AÏDA), CIRAD, University of Montpellier, Montpellier, France
*Corresponding author: maroteav@gmail.com

ABSTRACT

Noble sugarcanes are used in several cases of rum production and have a specific agronomic behavior as their morphologic characteristics are different from those observed in modern cultivars. Their height and tillering don't allow good yields under conventional methods of cultivation. They produce less stalks than modern cultivars on the same plant. Therefore, to get the same quantity of stalks per unit of surface, the population density has to be changed from standards. To study the impact of different densities on the cultivation of noble canes, the leaf area index (LAI) of noble and modern varieties was measured to know their capacity to cover the soil and prevent weed development. The cultivar To re'are'a (*S. officinarum* noble variety) was used with good agronomic potential, on an experimental plot of 4 000 m2 where two densities of plantation from 20 000 to 40 000 plant per hectare were compared, under the same cultivation standards. The doubled density plots showed better LAI (4,52 compared to 2,25 for low density), which increased month after month. Indeed, biomass yields were also higher (108,0 compared to 47,5 t/ha for the low density). Doubling the density of this noble cane could be a good agronomic practice to explore some better schemes of cultivation, adapted to organic agriculture. A special focus will be put on an intergeneric hybrid of *Saccharum officinarum x Miscanthus floridulus* called To 'a'eho (LAI = 6,65) to investigate the management of weeds inside the row.

Key-words: *Saccharum officinarum, Leaf Area Index, population density, plantation, noble sugarcane, organic agriculture.*

INTRODUCTION

Density of conventional sugarcane plantations is worldwide accepted at around 20 000 plants/ha (standard 1,8m row spacing also called inter-row) mainly depending on mechanized operations such as plantation and harvest (Fauconnier, 1991). Density also depends on the context, for example, if needed, inter-row can be reduced at minimum 0,9m or applied in paired rows such as 30:150cm with good results (Kumawat and Dahima, 2016). Therefore, in Reunion Island, where paired rows 50:140cm are usually applied (Poser et al., 2018), temperatures and soils are different following altitude and it has an influence on weed growth but also on both vegetative cycle and maturation of sugar and the density of plantation has to be adjusted following these parameters (Pouzet and Lienhart 1998;. Pouzet et al., 1999). Under organic sugarcane farming systems, minimizing row spacing is expected to preserve the soil from solar exposure and reduce weed development. It allows the plants to close the rows as soon as possible, but at the same time, row spacing has to be sufficiently wide to allow mechanized weed removing (Vitrac et al., 2019a). This is particularly true with varieties of noble *Saccharhum officinarum* which grow slower than *Saccharum* spp. (Vitrac at al., 2019b). As *Saccharum officinarum* noble canes are not cultivated any more from the beginning of the 20th century, very few studies were conducted on its growth and all agronomic parameters. However, there is a very special interest regarding these old varieties in small contexts of high valuable rum production (Vitrac et al., 2018a). Some distilleries in the Caribbean and Polynesia are used to produce rum with them and also under organic certified standards. They believe that old *Saccharum officinarum* varieties can bring to the rum very special aromatic flavors. For example, in the island of Tahiti, Vitrac *et al*. (2019b) showed the historic interest of Otahiti variety as they explored its culture under organic standards. These authors have proposed a list of pests regarding weeds (Pouzet et al., 1999) and also regarding other arthropods and rats (non published data). They finally concluded that conventional density of plantation is unadapted to *Saccharum officniarum* global production.

Vitrac *et al.* (2019a)) showed that modern *Saccharum* spp. have a tillering about 8 stems per plant contrary to some *Saccharum officinarum*, used for rum production, which had about 4 stems per plant. The hypothesis was then to double the density of noble cane to get the same amount of stems per unity of surface than *Saccharum* spp. increasing then the biomass production. Increasing density should also influence the capacity of the plant to capture the light to produce sugar and to reduce the weed development (less access to light by covering the soil), as the LAI (Leaf Area Index) increases the efficiency to capture light (Launay et al., 2019). We based our observations using a LAI approach to: (1) determine the theorical LAI of the varieties used and (2) measure the evolution of LAI for standard and doubled densities. The biomass yields comparing these two densities were also measured. Finally, in our experiments and measurements, the variety of *Saccharum maximum* called To'a'eho showed a very high theorical LAI. Due to this specificity, we discuss in this paper the interest of using this native intergeneric

hybrid *Saccharum officinarum* x M*iscanthus floridulus* (Vitrac et al., 2018a)) as a mean for organic weed management with the great interest that it could be harvested at the same time than *Saccharum officinarum* noble canes for rum production with a Brix degree of more than 16° (Vitrac et al., 2018a).

The objectives of this study is (1) to determine theorical LAI of sugarcanes as some *Saccharum* sp. modern cultivars, *Saccharum officinarum* cultivars and To 'a'eho intergeneric hybrid (*Saccharum officinarum* x M*iscanthus floridulus*), to (2) propose a strategy of biomass yield improvement of *Saccharum offciniarum* To re'are'a doubling the density of standard plantation (20 000 to 40 000 plants/ha) and characterize it by a LAI approach to help the rum producers demand.

MATERIAL AND METHODS

Agricultural practices in organic sugarcane

All the fields studied were organic certified for both European (UE) and Pacific rules (NOAB, in French language: Norme Océanienne d'Agriculture Biologique). Vitrac et *al*. (2018a) defined the following soil preparation and cultural practices: before planting, the soil was worked to a depth of 15 cm then furrowed in twin rows, close together: 50 cm and distant from each other's of 1.60 m. This spacing of 1.60 m (inter row) allows the passage of a small 4x4 tractor of 16 Horsepower (HP) equipped with a rotary cutter with blades allowing the mechanical weeding over 1.1 m in width. The arrangement in double rows makes it possible to densify the planting, the double row having to end up merging into a single and wide row. Due to the scarcity of plant material from recent local surveys, planting was carried out with 8-week-old plants raised in the nursery from one-eye cuttings (Poser et al., 2018). The seedlings were manually transplanted into the furrows at 50 cm intervals and in staggered rows, their survival rate was close to 100%. The weeding on the row was carried out using a "serpette", the local name for a small manual hoe.

Organic compatible organo-mineral fertilization consisted of three inputs of distillery vinasses (20 t/ha, source of K), composted horse manure (5 t/ha, source of NP) and crushed dolomite (2 t/ha, source of CaMg), applied directly, mainly in the rows at the foot of the canes. These organic fertilizers were applied for the first time after the first post-planting weeding. Rainfall and temperatures were recorded using an automatic gauge between January 2018 and October 2020.

Experimental plots

An experimental collection plot (17°43'49.1"S 149°34'47.7"W) about 240m2 was installed in December 2019 with 16 sugarcane varieties: imported noble *Saccharum officinarum* (Black Cheribon (BC) and Batavia (BAT) from Cirad visacane®); modern varieties *Saccharum spp.* (Jaune roseau (JR), B69566 from visacane®, Rouge à Reflets Verts (RRV) and Blanche (Bla)); Polynesian noble *Saccharum officinarum* (irimotu, o'opu, ute, piavare, jaune à tâches rouges (JTR), rutu, re'are'a, oura and pourpe à bandes vertes (PBV)) and Polynesian *Saccharum*

maximum (to'a'eho). For each variety, 60 plants were planted on 2x6m plots, with about 0,5m row spacing (20 000 plants/ha), without any replications.

On 19th of October 2020, 3 plants were sampled to measure the LAI (Leaf Area Index) with the method described by Hermann & Câmara (1999) in the following procedures: for each plant; (i) on the main stem we counted the number of green ray leaves (first fully emerged leaf at the top with a visible dewlap at the junction of the leaf blade and the leaf sheath) on the main cane stalk and for each leaf its length and width were measured; (ii) the number of tillers was determined and for each tiller the number of green ray leaves (N), their length (l) and width (w).

Leaf surface : Ls= l*w*0,75*(N+2) ; 0,75 being the coefficient of leaf shape

LAI : (Ls(main stem)+ Ls(tillers)*tillers average *(density(plant/m²)).

Additional "Fischer" experimental plot

This site (17°45'30.1"S 149°17'21.4"W) was the first plantation of organic certified sugarcane plants in 2013 on old pineapple fields stopped in 2007. It was renewed and grown with varieties of noble canes in 2016 on 4 000 m^2, a plot where most of the research program regarding noble varieties were usually conducted from 2016 to 2019 (Vitrac et al., 2018a).

In April 2020, it was renewed for the second time on the same surface. The variety chosen was re'are'a (called JRP (Vitrac, 2019b)) because of its good yield potential despite low tillering which is the component to improve. For each density, 3 doubled rows were planted with two densities tested: 20 000 plants/ha (d1) and 40 000/ha (d2), the only difference being the space of 25cm between each plant on the same row (d2) compared to conventional practice at 50cm (d1). A Fisher plot design was implemented with 3 blocks following a regular slope about 3% (Figure 1).

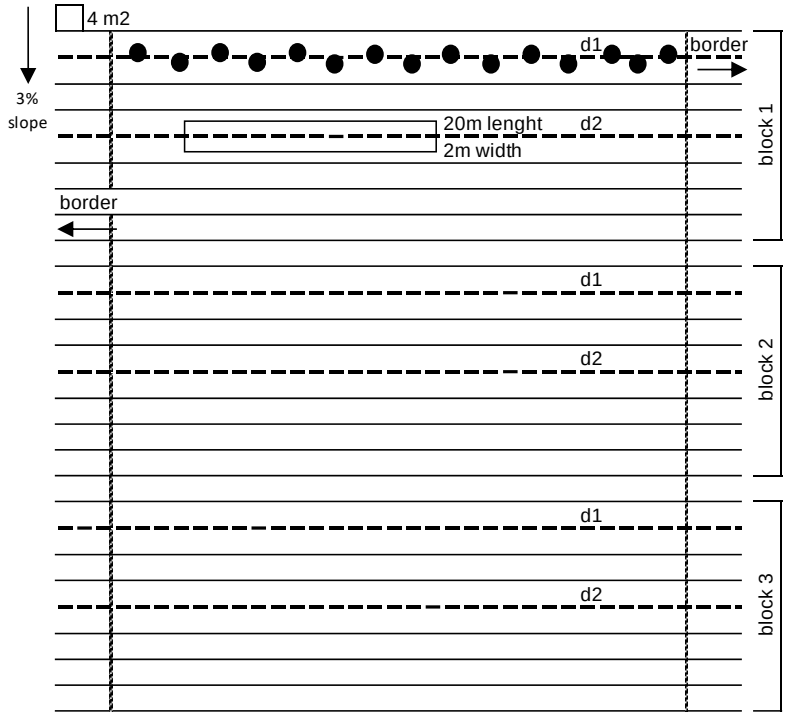

Figure 1: Fischer plot design of the additional experimental area. d1 (20 000 plants/ha) was compared to d2 (40 000 p/ha). 15 plants were sampled on the middle row to avoid border effects (black circles). Plants were counted inside an area about 20m length around the row to determine the measured density.

Measurements

Regarding the "Ficher" additional plot, ray leaves surfaces were measured and repeated every 4 weeks which is the necessary time for the plant to produce 3 new leaves (Castro-Nava et al., 2016). These measurements were conducted on 15 plants on 13/10/20, 19/11/20, 15/12/20 and 08/01/21 (Figure 2) in the middle row of each density to avoid border effects (Figure 1). Inside this row, we counted the number of plants for 40m2 (20m length x 2m corresponding to the width of the row) to determine the "measured density". Measured leaves were marked to sample only the new leaves.

For each plant we measured the number of stalks, the number of ray leaves per stalk, the length (l) and the width (w) for each ray leaf. Global Leaf surface (Ls= l*w*0,75*(N+2) ; 0,75 being the coefficient of leaf shape ; number of green ray leaves (N), their length (l) and width (w)) was then determined following method proposed by Hermann & Câmara (1999) and LAI as well by the following: LAI = (Ls(main stem)+ Ls(tillers)*tillers average *(density(plant/m²)).

The theorical yields were measured by harvesting stalks 15 samples. They were then weighed and multiplicated by the "measured density" and then reported to the corresponding surface of soil and yield finally estimated in tons / ha.

Statistics

Regarding the Fischer plot design and in order to compare the two densities d1 and d2, data were analyzed using the statistical software XLSTAT 19.4.45191. A population probability law (normal distribution) and descriptive statistical parameters such as mean and standard deviations were processed. Means comparison tests of Mann Whitney (samples<30) were used to compare LAI and weighed biomasses.

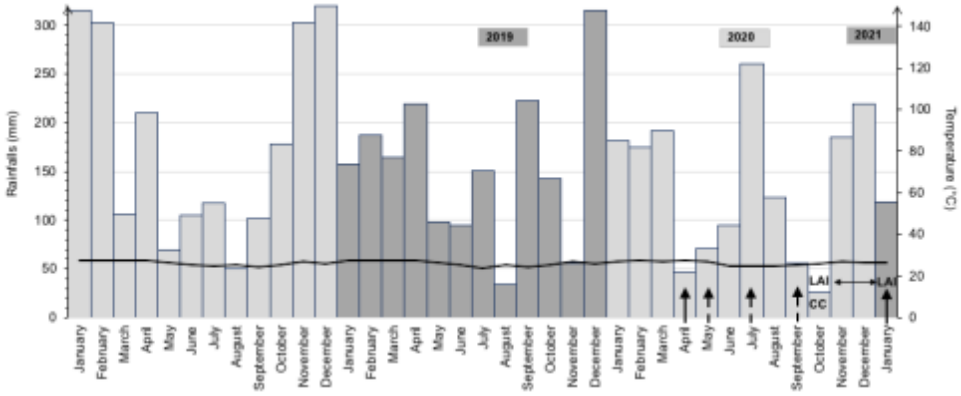

Figure 2: Pattern of rainfall and temperatures and successive operations since planting in April 2020 for the "Fischer" plot (black arrows show plantation and harvest in late January 2021). Discontinued black arrows (May, July and September 2020) shows operations of maintenance (mechanical and manual weed removing). CC: Cane Closure of rows; LAI: period of LAI sampling.

RESULTS AND DISCUSSION

In the experimental collection plot, modern varieties theorical LAI averaged is about 5,18 (Figure 3). It was significantly higher from both native and imported noble *Saccharum officinarum* (p=0,05) which had an average LAI between 2,69 and 3,34. This result confirms the observations of Vitrac *et al*. regarding tillering of noble varieties which have less stalks per plant than modern cultivars and consequently less leaves and soil covering aptitude as well. It confirms too the hypothesis that we can improve soil covering of cultivated noble canes by doubling the density of plantation. It is especially the case for the plot regarding the chosen re'are'a variety (LAI =1,83).

The LAI values we found regarding the "Fischer" plot experimentation with re'are'a variety were between 3,75 and 4,52 for doubled density (d2, Figure 4), which is a little bit more than what (Gomes da Silva et al., 2017) found for modern varieties (between 3,66 and 4,46). Therefore, for simple density (d1) the LAI were

between 1,72 and 2,25 which is close to theorical the value of 1,83 which is the lowest (Figure 2). However, Vitrac *et al*. showed it has the highest biomass yield of *Saccharum officinarum* canes tested. It confirms that doubling the density of plantation of noble *Saccharum officinarum*, by using the method we propose, can improve their LAI so it can reach the level of modern varieties. To resume, it can reach a LAI about 4,52 when its density is doubled, becoming close to modern varieties (13).

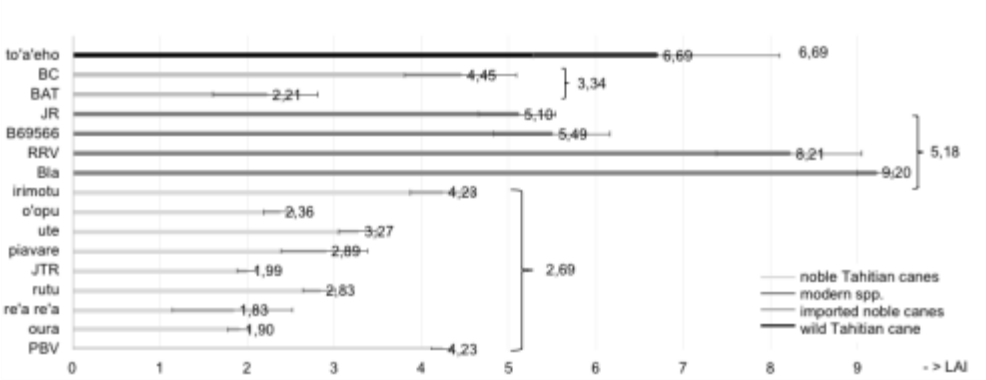

Figure 3: Theorical LAI values of all canes estimated in the experimental collection plot and average LAI of cane categories.

We observed no significant difference between the periods tested (p=0,05) for both d1 and d2 (which were significantly different, p=0,05) and a very small LAI increase from the first observation to the last (Figure 4). Actually at 220 days of growth, the rows were already closed and the LAI values observed were only linked to the density.

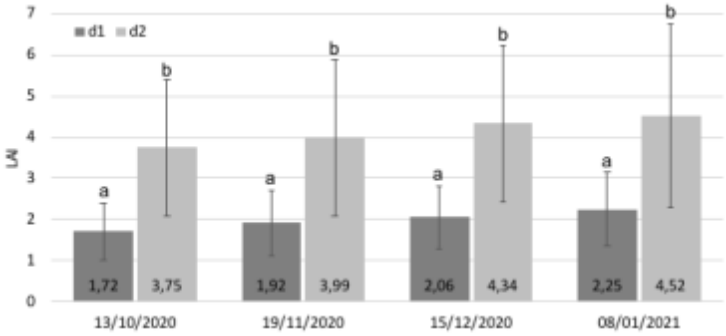

Figure 4: "Fischer" plot: comparison between LAI of densities d1 and d2 (re'a re'a variety) and evolution of the LAIs from the 13/10/20 to the 08/01/21. Results of Mann&Whitney test (sample < 30; p=0,05) are shown by letters a and b.

Vitrac *et al*. (6) observed that weeds had a very important influence on *Saccharum officinarum* fields and it could be interesting to renew this experimentation to evaluate the impact of weeds on a doubled density plot. It then could be shown that

improving LAI of *Saccharum officinarum* is able to influence weed development as well. However we didn't measure it from the tillering stage and Vitrac *et al*. showed that noble canes had a lower growth than modern varieties. During the boom stage, the sugarcane is very sensitive to weeds development, and organic agriculture do not allow the use of pesticides and farmers have to permanently tolerate an amount of weeds. They remove it mechanically and by hand (Vitrac et al., 2019a) which represent 80% of production costs (Vitrac et al., 2018b). Even though improving LAI might not reduced the production costs of *Saccharum officinarum* for farmers, it definitely allows to obtain more stalks at harvest, thus increasing their income.

This is what we observe with an approximate the biomass yield of 110 t/ha for d2 compared to 45 t/ha for d1 which is also linked to density (Figure 5). The measured biomass yield of d1 is approximately the same as Vitrac *et al*. found (50 t/ha). It indicates us the reliability of our data collected in our experiments.

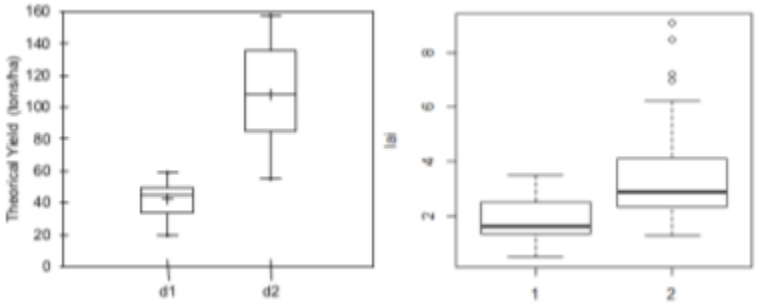

Figure 5: box plot of "Fischer" plot theorical yields (tons/ha, on the left) and global LAI (on the right) regarding densities d1(1) and d2(2) (re'a re'a variety).

Contrary to this result, Gomes da Silva *et al*. showed that there is no correlation between LAI and biomass yield contrary to our unusual conditions: *Saccharum officinarum* x organic agriculture. Their study is actually based on conventional agriculture and modern varieties. It shows us that organic agriculture with the use of *Saccharum officinarum* varieties (which has lower LAI, Figure 3) has to be regarded with different method and standards. This assumption is shown by the Figure 5: LAI is linked to density and correlated to the biomass yields. It is therefore useful to determine the LAI which can give a good idea of the density to apply for *Saccharum officinarum* fields.

The method we used is time consuming and is then not applicable for a farmer. Tournebize et al. (2007) proposed a method using photos and numeric data treatment to measure LAI without destroying any leaves or stems. It can indicate whether a density of plantation is adapted or not and also allow to follow cane stalk densities on long periods to see for example the influence of fertility on plant growth. Acquisition of satellite images is also a great tool to evaluate the density of a plot (Gate et al., 2019). It could be useful to evaluate at the scale of a field the observations made at a small scale, allowing to observe agronomic items such as fertility impact and how it can be correlated to density. For example, in some

organic agriculture context, fertilization has to be managed with organic fertilizer (contrary to inorganic) and it has different impacts on plant growth due to the composition of the fertilizer and to the period and method of application (Bokhtiar and Sakurai, 2005). Density could also influence morphologic parameters such as height, diameter, internodes length and tillering showing competition between plants and the limits of densifying a culture (Launay et al., 2020). LAI can help to indicate us theses correlations and this index has a very special interest for *Saccharum officinarum* organic fields.

Finally, we observed that To'a'eho variety had a theorical LAI of 6,69 (not significantly different from modern varieties, p=0,05) which is more than the average of modern varieties (5,18, Figure 3). This is a native inter generic hybrid of Polynesian *Saccharum officinarum x Miscanthus floridulus* (Vitrac et al., 20168a ; non published data). This variety is harvestable and could easily be used for weed control inside the rows. The reason is that even if their leaves are thin, the tillering is about 30 stems by plant allowing a very good soil covering from the first stages of growth. Therefore, an association with *Saccharum officinarum* re'are'a which show exactly the opposite could be very productive.

CONCLUSION

As *Saccharum officinarum* is no more cultivated for sugar production, few studies are available and high valuable rum production is still the only reason which justify its use. However, at the same time, new information allows us to think that several characteristics could be interesting to develop, especially under organic agriculture context. For example, useful varieties to manage weeds such as To'a'eho, a wild sugarcane is worth trying in sugarcane production as it is also easily harvestable.

The measured LAI in field indicated that determining the right density to improve *Saccharum officinarum* behavior in organic agriculture context is a reliable method and from our experiments it is correlated to biomass yield.

We then have the possibility to follow the LAI of this type of fields with numeric methods which give key agronomic indicators to continue to improve this high valuable agriculture for rum production.

Finally, under organic certified standards, doubling the density of *Saccharum officinarum* To re'are'a gave us good agronomic results regarding the biomass yields. This could be improved by the use of To 'a'eho intergeneric hybrid of *Saccharum officinarum x Miscanthus floridulus* inside the row to prevent the development of weeds.

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WOMEN'S EMPOWERMENT IN WESTERN CHINA: MEASUREMENT, DETERMINANT FACTORS AND ITS CORRELATION WITH POVERTY

Jing WANG[1,2,*], Rui GU[2], Fengying NIE[1], Thomas DOGOT[2]

[1]Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing, China

[2]Economy and Rural Development Department, Faculty of Gembloux Agro_Bio Tech, Liege University, Gembloux, Belgium
*Corresponding author: gurui@caas.cn

ABSTRACT

Women's empowerment is a key focus of the Sustainable Development Goals. It is also an element in China's national poverty reduction strategies. As most poverty identification, alleviation, and graduation strategies are targeted on households rather than individuals, the status of rural women's empowerment remained insufficiently studied. This paper examines the status of women's empowerment in the formerly poverty-stricken rural areas in western China, using data obtained in 2021 from a questionnaire-based survey on 1027 rural households in seven counties of four provinces. It constructs a women's empowerment index with 10 indicators in five domains – production, resources, income, leadership, and time use – based on women's empowerment theories and practices in agriculture. The study finds that the average level of women's empowerment is 0.654. Women are most empowered in the time use domain while least empowered in the leadership domain. Logistic regression results reveal that women's ages, women's educational years and the decision-making in women's parental families are significant determinants of women's empowerment. Further studies indicate that the role of family legacy is getting weaker in younger generations and stronger among spouses with closer ages. The household relative poverty status has no significant effect on women's empowerment in this study, which implies that in rural areas, sociocultural factors might outweigh economic factors in determining women's empowerment.

Keywords: Women's empowerment, Rural household, Poverty reduction, China.

INTRODUCTION

Women's empowerment is a key focus of the Sustainable Development Goals outlined in the UN 2030 Agenda. It has also become a prominent and widely debated research topic, particularly in the context of policy-making for economic development. The concept and measurement for women's empowerment varies

across difference social and cultural background (Priya *et al*, 2021). The Women's Empowerment Index in Agriculture (WEAI) developed by IFPRI, OPHI and USAID has been widely used to measure women's empowerment, particularly for rural women and in agriculture. Alkire (2013) introduced, among others, its rationale, method and computation.

The demographic characteristics of women, family structure, spousal differences and context-specific features such as travel time to paved road, distance to market, farmland owned (Adekunle et al., 2021; Didana, 2019; Sell & Minot, 2018) are commonly used factors to explain women's empowerment. In most findings, women's age and education were significant determinants for women's empowerment. Women's empowerment is associated with poverty reduction. In developing countries, higher gender equality was more likely to be associated with lower poverty rates (World Bank, 2001). In rural China, Huang et al (2018) found that household poverty was positively associated with women's disempowerment. Household poverty status is also explored as a determinant of women's empowerment. Assaad et al (2014) used per capita expenditure to define household poverty status and found that its significance on women's empowerment was not the same among quantiles and not stable after adding control variables. While per capita consumption was a significant determinant of women's empowerment in the urban areas, it was on the contrary in the rural areas (Khan & Awan, 2011).

Women's empowerment has been an element in China's national poverty reduction strategy. Many projects targeting women and girls, such as skills training, microfinance, reproductive healthcare, and compulsory education for girls, alongside gender-neutral initiatives like rural infrastructure development, relocation programs, and migrant worker support, have significantly improved the living standards and welfare of women and girls (Wang & Jia, 2012). China eliminated extreme poverty in 2021 and published four national poverty alleviation survey bulletins to map its outcome (National Bureau of Statistics, 2021). However, as household was the basic unit for poverty graduation, the status of rural women's empowerment has not been sufficiently measured and remained less reported.

Therefore, this study aims to examine the status of women's empowerment in the formerly poverty-stricken rural areas in western China; what factors determine women's empowerment and whether poverty reduction has an effect on women's empowerment.

MATERIALS AND METHODS

Data source

This paper used the data obtained from the Rural China and Food Security Household Longitudinal Survey conducted by the Agricultural Information Institute of the Chinese Academy of Agricultural Sciences in 2021 in seven counties of four provinces in western China. These counties were among the list of 592 poverty-stricken counties identified by the Chinese government in 2011. Villages were sampled through the Probability Proportion to Size (PPS) method

and households followed the random sampling method. A total of 1556 households were surveyed through a nine-module questionnaire, which included a module on the measurement of women's empowerment in agriculture. For this study, we restricted samples to 1027 households with both male and female adults, and with all the activities asked in the women's empowerment module.

Women's Empowerment Index (WEI)

The index we used in this paper was adapted from WEAI. We adopted identical five domains (production, resources, income, leadership, and time use) with the original WEAI but modified the indicators to fit the conditions of agriculture and rural areas in western China. After defining whether women were empowered or not on each indicator, we could get individual women's inadequacy score *Ci* and define whether a woman was empowered or not at the cut-off value *k*, which was 0.2 in this study. By multiplying the disempowered headcount ratio (Hp) and the average inadequacy score of disempowered individual women (Ap), we could get women's disempowerment index, which was represented by M_0; WEI equaled the value 1-M_0. M_0 allowed us to evaluate women's disempowerment decomposed by indicators, dimensions, or population groups.

Household poverty

In this paper, we adopt the concept of relative poverty. According to Xing (2019), when the per capita household annual income is below 40% of the income median, the household is considered to be in poverty. Here, the household annual income is the total income minus production cost. the total income is the sum of wage income, farm and family business income, transfer income, and property income.

Logistic regression

The dependent variable WE is a binary variable representing women's empowerment status. If women were not empowered at the cut-off value of 0.2, WE = 1; otherwise, WE = 0.

$$ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 \text{Poverty} + \beta_2 \text{Female} + \beta_3 \text{Couple} + \beta_4 \text{Legacy}$$

where p = the probability that WE=1, $1-p$ = the probability that WE= 0. Poverty is a binary value where poverty =1 if the per capita household income is below 40% of the income median and poverty = 0 if it is not. Female is the vector for women's individual characteristics, including women's age, years of education and whether women had wage income for the past 12 months. Couple is the vector for the difference in age and years of education between couples, calculated by wife minus husband, reflecting the relative power of women over men. Legacy is the vector related to parents' family, including the decision-making in women's parental families (the value was 1 if decided solely by men; otherwise, the value was 0) and the relative economic status of women's parental families to their husbands' parental families (1 worse, 2 the same, 3 better).

RESULTS AND DISCUSSION

Women's empowerment status

It is calculated that M_0 for the sample households is 0.346, meaning that WEI is 0.654. This is a moderate gap compared with M_0 reported in previous studies applying the WEAI method (Sraboni et al., 2013; Gupta et al., 2017; Huang et al., 2017). The gap reflects the contextual and flexible nature of the Index, as indicators could be different across studies. By decomposing M_0 by domains and indicators, we find the leadership domain contributes to nearly half to M_0 while the income and time domains add up to less than 20% (see Table 1). The indicator on group leadership contributed most to M_0. The time burden for women in our survey seems to be very low as only 1.64% women in our survey are inadequate on the time burden indicator. The second smallest contribution to M_0 is the indicator on control over daily necessity consumption. These results indicate that women in our survey enjoyed a high level of freedom in time. They are more empowered in domestic and economic affairs than in public affairs.

Table 1. Contribution to M_0 by Domains and Indicators.

Domain	Domain Contribution to M_0	Indicators	Indicator contribution to M_0
Production	16.99%	Input in farm decisions	8.08%
		Input in non-farm decisions	8.91%
Resources	17.91%	Control of productive asset	8.67%
		Decisions on credit	9.24%
Income	11.17%	Control over necessity	3.75%
		Control over use of income	7.41%
Leadership	45.83%	Speaking in public	22.62%
		Group leadership	23.21%
Time	8.10%	Time burden	1.64%
		Freedom of time allocation	6.46%

Determinant factors of women's empowerment

We run 4 regression models successively as shown in Table 2. 28 observations are omitted due to incomplete data, leaving 999 households.

Table 2. Marginal Effects of the Determinant Factors on Women's Empowerment.

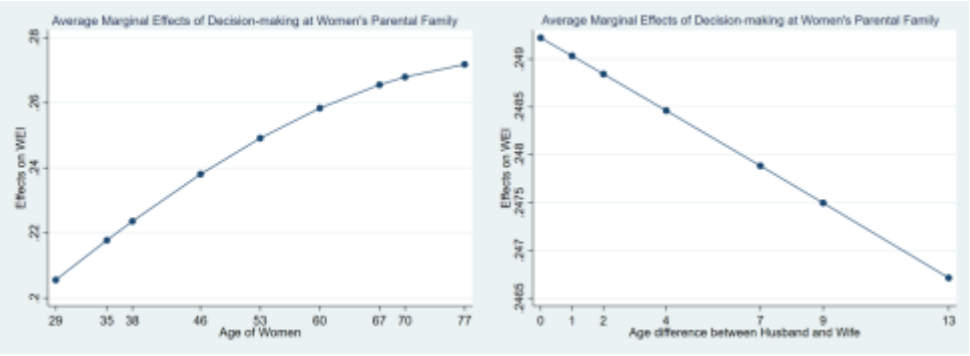
Y=WE	(1)	(2)	(3)	(4)
Poverty	-0.053	-0.050	-0.049	-0.053
	(0.035)	(0.035)	(0.035)	(0.035)
Age female		-0.005***	-0.005***	-0.005***
		(0.002)	(0.002)	(0.002)
Education female (years)		-0.012***	-0.009*	-0.009*

Y=WE	**(1)**	**(2)**	**(3)**	**(4)**
		(0.004)	(0.005)	(0.005)
Wage income female (dummy)		-0.011	-0.008	-0.010
		(0.036)	(0.036)	(0.034)
Age difference			-0.004	-0.003
			(0.004)	(0.004)
Education difference			-0.004	-0.002
			(0.005)	(0.005)
Decision-making of women's parental families				0.248***
				(0.025)
Economic status of parental families				-0.005
				(0.026)
Observations	999	999	999	999

Note: 1. Standard errors in parentheses
2. *** p<0.01, ** p<0.05, * p<0.1

We find that women's ages, women's educational years, and the decision-making power in women's parental families have significant effects on women's empowerment. As shown in column (2)-(4), women's age and their educational years have significant negative effects on women's dispowerment, which suggests that the increase of women's age and education may contribute to women's empowerment. The marginal effect of a given explanatory variable captures the change in the probability of observing an outcome due to a unit change in the explanatory variable. As shown in column (4), the decision-making power in women's parental families has a significant positive marginal effect on women's empowerment, holding other factors fixed, the predicted probability of women's disempowerment is about 24.8% higher for women's parental families whose decisions are made solely by men than for those are not. Such marginal effect become stronger as women's getting older, as shown in Figure 1(a), indicating that the role of family legacy is getting weaker in younger generations.

Although no direct evidence of heterogeneity of marriage is shown from the results of regression, we find that the average marginal effect of women's parental families on WE become stronger as women's ages are getting closer to their husbands' ages, which can be seen in Figure 1(b). Bertocchi et al (2014) had a similar finding that the probability that a wife was responsible for intra-household decision-making had increased as the wife's age became closer to her husband's.



(a) (b)

Figure 1. Average Marginal Effects of Decision-making at Women's Parental Families.

Interestingly, whether women had wage income for the past 12 months seems to have no significant effect on women's empowerment. This is probably because women in our sampled households are mainly engaged in agricultural production. In our survey, less than 27% of women had wage-income and the ratio of women's wage income to the total household income was 10% on average.

Poverty and women's empowerment

In this study, we find that poverty status has no significant effect on women's empowerment. This result could be partially supported by a study on the policy effect of the national poverty alleviation campaign for women, which found the campaign had no significant effect on non-farm employment for rural women in the western regions and for women with primary school education years and lower (Sun & Sun, 2022). In our survey, women in sampled households shared the similar features, that is, they all lived in western regions and 75% of them had less than 6 years of education. In addition, more diversified poverty measurement methods, except the binary poverty status defined solely by an income threshold, are worthy of further studies in order to better analyze the relationship between poverty and women's empowerment.

CONCLUSION

This study finds that rural women in the formerly poverty-stricken areas in western China enjoy an overall moderate level of empowerment. They are more empowered in the domestic domains than in the public domains. Women's ages, women's educational years and the decision-making of women's parental families are found to be significant determinants of women's empowerment. The effect of poverty reduction on women's empowerment needs more exploration. For example, multiple poverty measurement methods should be further studied by discussing different poverty thresholds or by using multi-dimensional variables to define poverty. Sociocultural factor such as the influence of women's parental families on decision-making has a strong effect on women's empowerment in our

study, which implies progress in women's empowerment could be very slow to achieve but changes do happen as the marginal effect of parental-family influence is smaller on younger women.

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OPERATIONAL AND TECHNICAL TESTING OF TWO TYPES OF TRACTOR RAKES IN MOUNTAINOUS AREAS

Milan JUGOVIĆ[1], Miodrag ZORANOVIĆ[2], Zoran MALIČEVIĆ[2], Mladen IVANIŠEVIĆ[3], Tanja JAKIŠIĆ[1], Darko MARKOVIĆ[1]

[1]Faculty of Agriculture, University of East Sarajevo, Bosnia and Herzegovina
[2]Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia
[3]Faculty of Agriculture, University of Banja Luka, Bosnia and Herzegovina
*Corresponding author: milan.jugovic@pof.ues.rs.ba

ABSTRACT

The paper presents the results of testing two types of the most common rakes in hilly and mountainous conditions (chain finger side delivery rake and finger-wheel side delivery rake). The average yield of green mass is 38.14 t/ha, ranging from 23.50 to 46.50 t/ha. At the time of hay windrowing, the average moisture content was 31.65%. The average width of the formed windrow by the rakes is 1.25 m. The aim of the study was to measure the basic operational parameters (surface productivity, working width utilization coefficient, losses made), as well as fuel consumption and the engaged power of the tested rakes. For the two types of rakes tested, the working width utilization coefficient was in the range of 0.87-0.80 for chain finger side delivery rake, and 0.82-0.73 for finger-wheel side delivery rake, at travel speeds of 5.15 - 7.02 km h^{-1} and 4.86 - 9.97 km h^{-1}, respectively. The performance of the rakes varied from 0.81-1.01 ha h^{-1} for chain finger side rakes and 0.72-1.31 ha h^{-1} for finger-wheel side rake. The total losses for chain finger rakes averaged 1.45-2.92% of DM yield. Finger-wheel side rakes achieved slightly lower loss values of 1.29-2.21% DM. Otherwise, as the moisture content of the hay decreased, its total dry matter losses increased. The hourly fuel consumption for chain finger rakes was 2.42-4.17 l h^{-1}, and 2.25-2.95 l h^{-1} for finger-wheel rakes, while the specific consumption was on average 3.60 l ha^{-1} and 2.82 l ha^{-1}, respectively.

Keywords: *chain finger side delivery rake, finger-wheel side delivery rake, productivity, losses, fuel consumption.*

INTRODUCTION

At the moment of mowing, the grass mass contains about 80% moisture. For high-quality implementation of hay preparation, it is necessary to reduce this moisture below 20%. The reduction of its content is usually carried out naturally on the surface of the stubble. That procedure can be improved by using appropriate devices to increase the convective surface of the plant mass and the surrounding air, i.e. its easier flow through the plant mass. By correctly choosing and using the

device, drying in the field can quickly bring the humidity to the level of efficient storage. The mowed mass is treated mechanically immediately after mowing. This treatment is based on loosening the swath, then turning it over, with the aim of releasing moisture more quickly. Various types of devices can be used to perform one or three of the mentioned operations for scattering, turning and collecting the mentioned mass of hay.

Machines for mowing and turning hay significantly affect the drying speed of hay. Koprivica et al. (2011) pointed out that in the process of preparing alfalfa hay in the field, the main problem was uneven drying of the plant mass in layers. After mowing, it is recommended to manipulate the mowed alfalfa, up to a humidity of 50%, with the use of rotary tedder. The decision to apply tedding must be made on the basis of a comparison of potential losses due to prolonged lying in the field against known losses due to shedding of leaves (Rotz, 1991). The operations of scattering and collection into a bundle are necessary in the process of drying the treated hay cut and its preparation for collection by presses or forage harvesters.

Rotz, (1993), in the examination of three different types of rakes (parallel bar, finger-wheel and rotary) monitored their productivity, necessary labor, fuel consumption, as well as dry mass losses. Ülger & Bastaban (1982) compared primitive manual rakes, horse-drawn cross rakes, finger-wheel, chain-type and cylindrical-drum side delivery rakes, while observing the basic exploitation elements: working width, speed of movement, fuel consumption and productivity.

Baling losses are greatly influenced by the moisture concentration in the hay. Alfalfa raking losses increase rapidly when hay moisture drops below 40%. Raking excessively wet hay will delay drying, and leaf losses can reach levels above 20% of dry matter if raking is done immediately before baling (Collins, 1995). Scattering is also done due to the increase in the exchange surface of the mowed plant mass with the local air-convection (milder compaction) and for more intensive air flow through the mass (Vranić et al., 2005). Hay tedders perform volume expansion from swaths, without changing their working width, making them loose and lifted from the stubble, and are designed for use in the early drying process, when the crop is less susceptible to breakage (Macdonald & Clark, 1987). A narrow swath can be formed with a mower and conditioner unit, without raking and other manipulations with the mass during its drying in the field. This slows drying and requires the swath to lie longer in the field for two days, resulting in potential losses due to weather conditions and rain (Rotz, 1991). Losses of hay during baling can significantly reduce the nutritional value of forage, especially legumes, due to the higher proportion of leaves, which are incomparably more sensitive to crushing than stems in the swath (Rotz & Abrams, 1988), (Buckmaster, 1990).

MATERIAL AND METHOD

Operational and technical tests of the two types of rakes most commonly used in hilly and mountainous areas were carried out during 2019-2020, on the family farm Jugović, Mokro, near Pale (43°52'39"; 18°36'24"). A plot of 1.5 ha, at 900 m above sea level, with a slightly inclined exposure in the northeast-southwest direction,

was chosen as the terrain for the application of the tested machines. The moisture content of the grass mass was determined by a laboratory method, a moisture meter for biomass, i.e. by determining the content of dry matter and its calculation per hectare.

Measurement of exploitation parameters and engaged energy was carried out to test four speed intervals per plot. The surface effect of the subsequent operations was determined by measuring their speeds and the coefficient of utilization of the working area. Losses during work operations were measured manually, after each pass during loosening and collection of mass into bundles, per meter due to the working width of the machines, on the part where the swath did not lie. During the operation of gathering into a bundle, the measurement of the working width of the rake was performed in one pass, from the edge of the untreated part to the formed windrow. In order to determine the production performance, the following were determined: movement speed ($\boldsymbol{V_t}$), working width ($\boldsymbol{B_r}$) and coefficient of utilization of production working time ($\boldsymbol{\eta_{pr}}$). The pure productivity ($\boldsymbol{W_{pr}}$) of the tested rakes was determined by the chronometric method, i.e. by measuring the working time, at appropriate movement speeds, using a form:

$$W_{pr}=0,1*V_t*B_r*\eta_{pr},\ ha\ h^{-1} \quad (1)$$

Fuel consumption was determined by the volume method with the instrument "Pirburg", type 116, and the engaged power to drive the machine with a rotary dynamometer, type DMN 10, category III (for the type with tractor PTO drive). Both types of rakes were powered by the same LTZ T40AS tractor unit.

RESULTS AND DISCUSSIONS

In hilly and mountainous conditions, chain finger side delivery rake (SIP FAVORIT 220) and finger-wheel side delivery rake are the most common. The first type gets its drive from PTO shaft of the tractor, while the second type has ideal resistance from the moved plant mass, with the condition that the supporting springs of the wheels are well adjusted. Recommended descriptive contact is "just off the surface of the soil".

Table 1. Technical characteristics of the rake SIP FAVORIT 220

Parameter	Unit	Value
Category of suspension points	-	I + II
Working width	m	2,2
Number of rows of elastic fingers	-	3
Required power	kW	12
Productivity	ha h^{-1}	up to 1,5
Length	m	1,3
Width	m	2,4
Weight	kg	215

Picture 1 chain finger side delivery rake

Picture 2 finger-wheel side delivery rake

A good construction of the rake, in interaction with adequate technical settings, is a significant factor in reducing total losses of hay, partially extreme in the mowing operation. For the quality work of chain finger side delivery rake, the subjective factor should meet two basic prerequisites: avoiding work in dried mass < 50-55% and avoiding direct contact between the tip of the fingers and the soil surface.
The average yield of green mass in the test of the mentioned types of rakes is 38.14 t/ha, ranging from 23.50 to 46.50 t/ha. At the time of collecting the loose mass of hay, its average humidity was 31.65%. The average width of the windrow formed by the rake is 1.25 m.

Table 2. Technical characteristics of finger-wheel side delivery rake

Parameter	Unit	Value
Category of suspension points	-	I + II
Working width	m	2,4
Number of wheels/number of fingers	-	4/40
Required power	kW	18
Productivity	ha h^{-1}	up to 3,6
Length	m	-
Width	m	2
Weight	kg	175

Working width and productivity of tested rakes

The finger-wheel rake achieved a maximum working width of 1.98 m at a speed of 4.86 km h^{-1}, and a minimum of 1.75 m at a speed of 9.97 km h^{-1}. Chain finger rake also achieved similar values of the working capacity, however, the test was not performed in the fourth gear, due to increased losses and sticking of the grass mass. The coefficient of utilization of the working width-τG, depending on the speed of movement, was in the interval 0.87-0.80 for chain finger rake, or 0.82-0.73 for finger-wheel rake. From the mentioned data, a significant dispersion of τG is evident, with a fairly high correlation coefficient R^2=0.9921 and R^2=0.8716 (Chart 1). According to the theoretical working width of the tested machines, chain finger rake achieved slightly higher values, due to easier and more precise guidance on slopes, unlike finger-wheel rake. In both cases, the joint was formed in two passes.

The reported values are slightly lower compared to those reported by Öztürk and Çelik, (2003), 112.0% for chain finger rake and 95.77% for finger-wheel rake. The higher values of the constructive engagement of the machine in the first case are the consequence of the distance between the part of the slope formed in the first and return stroke. The productivity of the rake was directly influenced by two basic factors: speed of movement and working width. The surface performance of the rakes, depending on the speed of their movement, varied in the range of 0,81-1,01 ha h^{-1} for chain finger rake, or 0,72-1,31 ha h^{-1} for finger-wheel rake (Chart 2), which is partially in agreement with the results of Öztürk and Çelik, (2003): 1,40 ha h^{-1} for chain finger and 1,52 ha h^{-1} for finger-wheel. Similar data were reported by Ülger & Bastaban (1982), 1,57 ha h^{-1} and 1,45 ha h^{-1}, respectively. Furthermore, Arin, (1982) reports effects of 1,03 ha h^{-1} for finger-wheel and 1,3 ha h^{-1}, for cylindrical side delivery rake, which is in agreement with research. According to the above, the productivity of the tested rakes was lower by 30-40% than the theoretical one, which was lower than results, reported by Öztürk et al., (2003) of 20-30%, at a movement speed of 7 km h^{-1}. They also stated the values of the surface productivity per unit of working area of 0.64 ha/h/m for chain finger rake and 0.61 ha/h/m for finger-wheel rake. The average values in the conducted research, depending on the speed of movement, were in the interval 0.42-0.66 ha/h/m for chain finger rake and 0.36-0.75 ha/h/m for finger-wheel rake.

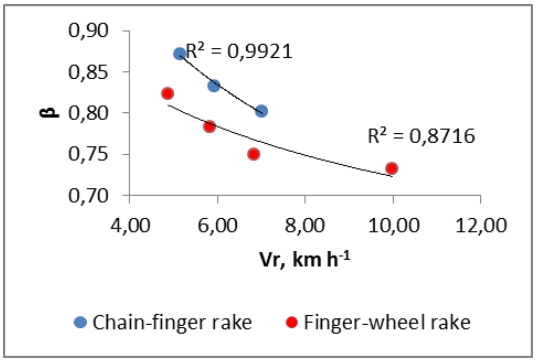

Chart 1 coefficient of utilization of the working width of the examined rake

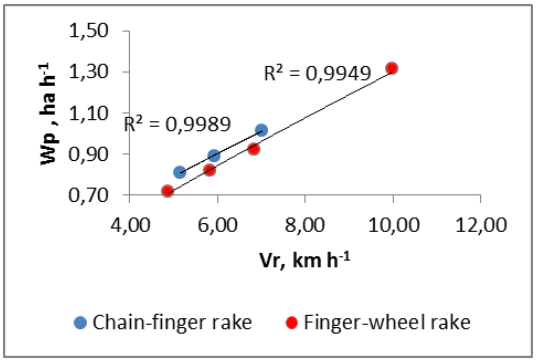

Chart 2 Production performance of the tested rakes

Rake losses, % of DM yield

When evaluating the quality of the rake work, the main factor is the amount of leaf mass loss, especially when handling dried material. Losses of hay during the operation of raking into a windrow represent all the unaffected plant mass, and for the most part, they are the result of the process of shredding the plants during mowing to a length of <10 cm. Depending on the type of rake, the degree of their general adjustment, the user's intuition, the condition of the grass mass, losses can vary in a wide range. Depending on the type of rake, the aforementioned losses

depend on the way the hay is moved. During the shorter journey of moving the hay, due to the reduction of its friction against the stubble, especially in the initial time interval, as well as the internal friction of the stalk against the stalk, leaf losses are significantly reduced.

According to the empirical assessment of Barać (2007), of the total cycle time for preparing hay from an adequate plant species, mowers participate with 20.4%, thus representing the basic source of the mentioned types of losses. However, with inadequate operational application of the rake, respecting all other factors, those losses can become extreme.

A linear increase in losses as a function of movement speed (on average 1.45-2.92% of the DM yield) is noticeable with the chain finger rake, with a correlation coefficient of R^2=0.9678. The obtained results are partially in agreement with the results of Öztürk, (1998), who stated their range of 2.51-11.83%, depending on the moisture content of the material during raking. Furthermore, by lowering the percentage of moisture in the hay, losses of dry matter increased. Finger-wheel rake achieved somewhat lower DM loss values, 1.29-2.21%, with a correlation coefficient of R^2=0.6311, Chart 3. Similar values for this type of rake were stated by Öztürk, (1998), 1.36-10.94%. However, slightly higher values were reported by Al-Gaadi, (2018), where total alfalfa baling losses were 18.50% DM of the total yield, while Twidwell, (1998), explicitly claimed that alfalfa baling operation achieved the highest loss of dry matter, average 5-15%. Based on laboratory research, Savoie, (1988) noted that hay losses were about six times higher for alfalfa than for grass hay, increased by lowering the moisture content of plants, and could be >20% for drier types of legumes. The maximum losses of rakes, when collecting clover and meadow grasses, were achieved by rakes with forced drive of fingers from tractor PTO, Barrington, (1970), Savoie, (1982) and Rotz, (1993).

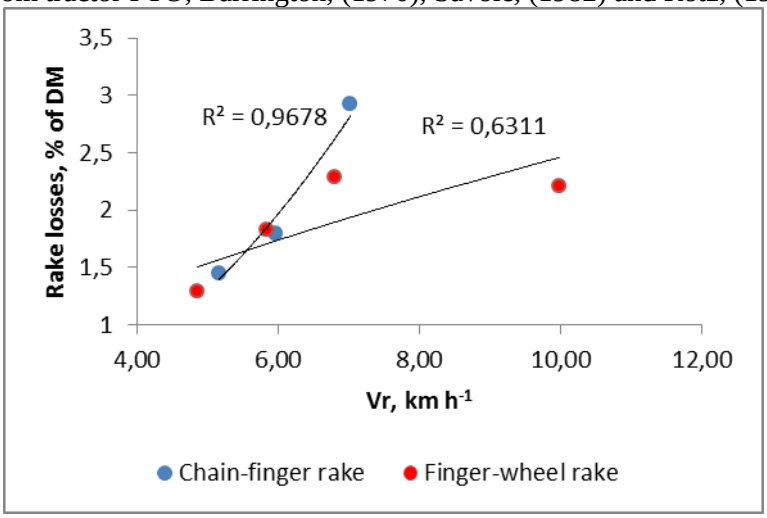

Chart 3 Losses of tested rakes, % of DM yield

Fuel consumption and engaged power of the tested rakes

Both types of tested rakes were driven by the LTZ T40AS tractor. The fuel consumption for the pure operation of the unit was 2,42-4,17 l h^{-1} for chain finger rake and 2,25-2,95 l h^{-1} for finger-wheel rake. The slightly higher consumption of chain finger rake was a consequence of the forced drive of the fingers from the tractor PTO shaft. In terms of specific fuel consumption, chain finger rake achieved 2,99-4,11 l ha^{-1}, average 3,6 l ha^{-1}, while finger-wheel rake achieved 3,13-2,24 l ha^{-1}, average 2,82 l ha^{-1}. Those values are lower than the statements of Öztürk, (1998), where the fuel consumption of chain finger rake was 9,0 l h^{-1} (6,21 l ha^{-1}), and finger-wheel rake was 8,9 l h^{-1} (5,91 l ha^{-1}). The obvious difference is probably due to the use of a higher power tractor. In the same treatment, the author states the engaged power for pulling the rake: 3.95 kW for the chain finger rake and 6.22 kW for the finger-wheel rake. The engaged power on the PTO of the examined chain finger rake, on average, was 10.33 kW, which is lower than the value of Öztürk, (1998), and was 5.99 kW of the total engaged power for propulsion and movement.

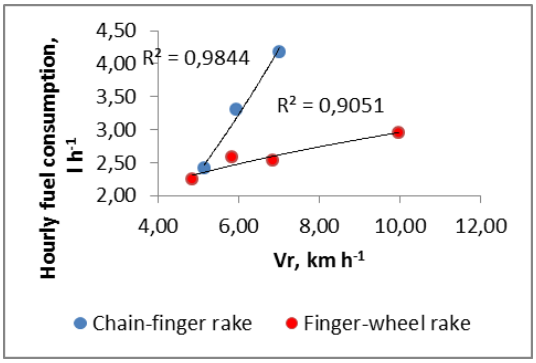

Chart 4 Hourly fuel consumption of the tested rakes, l h^{-1}

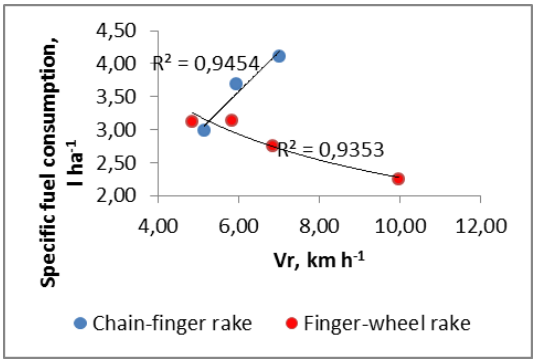

Chart 5 Specific fuel consumption of the tested rakes, l ha^{-1}

The chain finger rake achieved the maximum fuel consumption of 4,17 l h^{-1} at a movement speed of 7,02 km h^{-1}, and the finger-wheel rake had the minimum consumption of 2,25 l h^{-1} at a movement speed of 4,86 km h^{-1}. Chart 4 shows an approximate linear increase in hourly fuel consumption of chain finger rake, in contrast to finger-wheel rake, where the growth is milder, while in terms of specific fuel consumption, finger-wheel rake achieved 21.66% lower values. The reason for the increase in consumption and load was the accumulation of a larger amount of grass mass in front of the chain finger rake and its jamming between the grate hay remover from the fingers and the surface of the stubble, and for this reason they were tested in three speed modes. Unlike chain finger rake, finger-wheel rake did

not have the mentioned problem, which was in favor of lower engaged power and thus fuel consumption.

CONCLUSION

With the two types of rakes tested, the maximum working width was achieved by the finger-wheel rake of 1.98 m, while chain finger rake reached 1.76 m. The coefficient of utilization of the working width, depending on the speed of movement of the rake, was in the interval 0.87-0.80 for chain finger rake, i.e. 0.82-0.73 for finger-wheel rake. Surface effects as a function of movement speed varied from 0.81-1.01 ha h^{-1} for chain finger rake or 0.72-1.31 ha h^{-1} for finger-wheel rake. Total losses with chain finger rake had a noticeable linear trend of increase as a function of increasing movement speed, on average 1.45-2.92% of DM yield. Finger-wheel rake achieved somewhat lower loss values of 1.29-2.21% DM. Also, with the reduction of hay moisture, its total losses of dry matter increased. Hourly fuel consumption for chain finger rake was 2.42-4.17 l h^{-1}, i.e. 2.25-2.95 l h^{-1} for finger-wheel rake, while the average specific consumption of chain finger rake was 3.60 l ha^{-1}, and of finger-wheel rake it was 2.82 l ha^{-1}. The engaged power on the PTO of the tractor for the chain finger rake was an average of 10.33 kW. Both types of tested rakes have been used in production practice, and the main limiting factors for the choice are performance, losses of plant mass, fuel consumption and maintenance. Chain finger rake are characterized by operational cleanliness, good maneuverability, performing work operations while driving backwards, the ability to regulate the height of the wheels and a long service life. They are suitable for working on meadow hay, and often also for working on sloping terrain, while the relatively main disadvantages are smaller effects and somewhat greater losses of leaf mass. Unlike chain finger rake, the advantages of finger-wheel rake are: stable construction, the possibility of collecting hay in one, two or more rows, depending on the amount of grass mass, low fuel consumption, no forced drive and minimal maintenance as well as the purchase price.

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INFLUENCE OF LIGHTING SPECTRAL COMPOSITION ON THE DEVELOPMENT OF POTATO PLANTS IN VITRO

Tatyana LISINA, Konstantin KORLYAKOV*, Sofia SCHERBYONOK

Perm Agricultural Research Institute – the division of Perm Federal Research Center Ural Branch Russian Academy of Sciences, Russia
*Corresponding author: korlyakovkn@rambler.ru

ABSTRACT

The spectral composition of lighting at the stage of microclonal potato propagation is significant factor regulating physiological and biochemical processes. Optimization the lighting spectrum is promising not only for reducing energy costs in the production of healthy planting material, but also for increasing the reproduction rate. Two lighting treatments were used in laboratory experiment fulfilled in Perm Agricultural Research Institute in 2024.The first treatment was the OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), which has the necessary predominance of blue and red waves in spectrum necessary for plant photosynthesis as a whole. The second variant was LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%) recommended according to literature data specifically for in vitro potatoes. The experiment was carried out for 28 days. The influence of spectral composition of illumination on the stem, length, leaves and internodes number, potato tops mass, the content of photosynthetic pigments were explored. Five potato varieties: Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legend (ripeness group: early) were studied. As a result of the study, it was demonstrated that the use of optimized spectrum lighting led to the increase in the reproduction rate of potato during in vitro cuttings due to formation of internodes and leaves additional number, and stem length increase. The joint effect of lighting factors and genotype (hereditary factor) on morphological parameters was analyzed. It was revealed that the factor of lighting spectral composition influenced mainly on the length of plants and the number of internodes.

Keywords: potato, culture *in vitro*, light spectrum, photosynthetic pigments.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important crop for the economy of many countries. The quality of planting material determines the success of harvesting (Fedorova, 2016). Potato propagation in vitro culture is carried out to obtain healthy planting material. Light is a regulating factor for potato, so optimization of this particular factor plays significant role at the in vitro propagation stage. The spectral composition of the light source can be used to control the growth and

morphogenesis of potato tissues and organs in vitro (Lisina, 2023). Optimizing the lighting spectrum is promising due not only for reducing energy costs in the production of healthy planting material, but also for increasing the reproduction rate (Nakonechnaya, 2021). The necessity for the potato plant to receive the full spectrum of artificial lighting has been experimentally confirmed (Martirosyan, 2016). Many studies note the heterogeneity and inconsistency of the results obtained when studying plant growth processes under lighting of different spectral compositions, which is explained by the specific reaction of different plant varieties to light the spectral composition (Basiev, 2022). To achieve the greatest efficiency in the process of producing healthy potato seed material, it is important to develop technologies that take into account the biological characteristics of the genotypes under study. The purpose of our research is to study the influence of lighting of different spectral composition on morphological parameters and the content of main photosynthetic pigments in the leaves of potato microplants in vitro, varieties Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legenda (ripeness group: early), identifying varietal characteristics reactions to lighting conditions.

MATERIAL AND METHODS

The study was carried out from December 2023 to June 2024 in Perm Agricultural Research Institute – division of Perm Federal Research Center Ural Brunch Russian Academy of Sciences. Employees of agrobiophotonics laboratory constructed special research growbox. The growbox was located in a light-insulating cover to exclude the influence of natural light. Two lighting treatments were used in described laboratory experiment. The first treatments (A) was the use of OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), which has the necessary predominance of blue and red waves in spectrum necessary for plant photosynthesis as a whole. The second variant (B) was LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%) recommended according to the literature data specifically for potato in vitro (Kulchin, 2018; Lisina, 2023; Shanina, 2023). Lighting parameters were measured using a portable spectrometer UPRtek MK350S with a measurement range from 380 to 780 nm. Microclonal propagation of potato was carried out by cuttings under sterile conditions with further growing on Murashige-Skoog agar nutrient medium (Murashige, 1962). Chemical test tubes with 5 ml of nutrient medium were used as culture vessels. The nutrient medium was autoclaved at the temperature of 120°C for 22 minutes under 1.0 atm. pressure. Onwards 60 meristem plants of each variety were placed to growbox (30 plants of each variety per experimental variant) and cultivated at a temperature of 21-24°C and a 16-hour photoperiod. The experiment lasted 28 days (Fig.1).

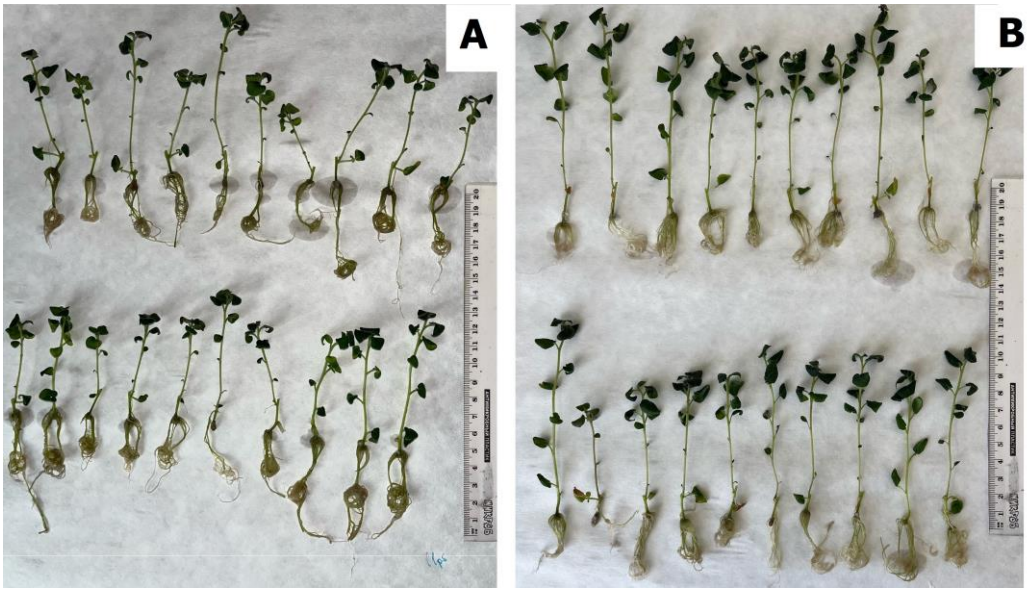

Figure 1. Meristem plants of the Irbitsky variety on the 28th day of the experiment. A - OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), B - LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%).

After this, scientists determined the mass of above-ground parts of the plants and root system mass. The content of photosynthetic pigments was determined by spectrophotometric method. The studied plant leaves were weighed and homogenized in 70% acetone. Carotenoids were determined at 440.5 nm wavelength, chlorophyll – 665 nm, and chlorophyll – 649 nm. Chlorophyll concentration in the extract were calculated using the Vernon formula (Trifonov, 2011). We used the Vertshtein formula to determine the concentration of carotenoids in the total extract of pigments (Trifonov, 2011). We determined the content of pigments in the studied material, taking into account the volume of the extract and the sample mass. Scanned images of plants were processed in ImageJ program to determine plant length and number of internodes. The obtained data were statistically processed using descriptive statistics, Student's t-tests and shift/position to determine the significance of differences between treatments (depending on the normality of the sample distribution). Differences between the compared values were considered significant with a confidence level of 95% or higher ($P \leq 0.05$).

RESULTS AND DISCUSSION

It was determined that significant excess in plant length was noted for all potato varieties participating in this experiment (Table 1). The number of per plant meristem is an important morphological indicator, as it determines the reproduction coefficient (Bakunov, 2021). A significant excess of internodes number in B

treatment compared with A was recorded for potato plants of Terra and Legend varieties (Table 1). Both varieties are early ripening. For Shah and Nevsky Irbitsky varieties (mid-early group), no significant differences in the number of internodes and leaves were recorded. The mass of plants above-ground parts for all varieties was higher in the experimental variant with LED lighting of the optimized spectrum. The mass of root system was higher under LED lighting in plants of Shakh, Irbitsky and Legenda varieties (Table 1).

Table 1. Morphometric parameters of plants cultivated under lighting of different spectral composition

Lighting treatment	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
Length of regenerated plants, mm					
OSRAM L 30W/77 T8 Fluora	65,3±3,5	66,6±1,7	55,7±2,9	81,4±1,7	46,8±2,1
LED light	81,9±4,2*	73,4±2,5*	97,4±3,8*	111,3±3,2*	86,2±3,2*
Number of internodes, mm					
OSRAM L 30W/77 T8 Fluora	7,3±0,3	5,8±0,3	6,6±0,2	7,05±0,3	4,9±0,2
LED light	7,2±0,4	5,7±0,4	6,5±0,2	7,5±0,2*	7,4±0,2*
Number of leaves					
OSRAM L 30W/77 T8 Fluora	10,2±0,3	7,7±0,3	9,0±0,2	8,85±0,2	8,3±0,2
LED light	10,1±0,2	7,8±0,2	9,5±0,8	9,7±0,2*	10,7±0,2*
Mass of root part, g					
OSRAM L 30W/77 T8 Fluora	0,129±0,010	0,162± 0,014	0,138± 0,009	0,145± 0,011	0,112± 0,010
LED light	0,209±0,011*	0,183± 0,015	0,171± 0,010*	0,141± 0,008	0,166± 0,010*
Mass of above-ground part, g					
OSRAM L 30W/77 T8 Fluora	0,133±0,010	0,155± 0,011	0,135± 0,011	0,135± 0,006	0,198± 0,009
LED light	0,252±0,012*	0,235± 0,019*	0,218± 0,011*	0,255± 0,009*	0,236± 0,008*

Notes:
* – significant differences between lighting treatments.

Analysis of variance of the obtained data allowed us to make conclusions about the contribution to the overall variability of the studied parameters separately from the lighting factor and the genotype factor, as well as their joint contribution (Table 2).

The factor of spectral composition of lighting made the greatest contribution to the variability of plant length and internodes number. Other factors, probably the composition of the nutrient medium, made a greater contribution to root system mass and the mass of the above-ground parts of regenerated potato plants.

Table 2. Contribution of the studied factors to the overall variability of the studied parameters, %

Factors	The studied parameters			
	Length of regenerated plants	Number of internodes	Mass of above-ground part	Mass of root part
Heredity factor (genotype, variety)	26	25	23	12
Lighting factor	42	33	19	12
Interaction of factors	13	17	18	18
Other factors	19	25	40	58

Assessing the functioning of the photosynthetic apparatus by determining the concentration of photosynthetic pigments is important indicator of plants response to changes in lighting quality (Nikonovich, 2018). The efficiency of photosynthetic apparatus of regenerating plants affects the synthesis of carbohydrates, which in turn affects the formation of mini-tubers (Golovackaja, 2013). The nature of changes in chlorophylls and carotenoids concentrations depending on the lighting spectrum turned out to be different for potato varieties taken as the objects of study (Table 3).

Table 3. Content of photosynthetic pigments in leaves , mg/g

Lighting treatments	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
Chlorophyll a					
OSRAM L 30W/77 T8 Fluora	232,87± 11,89	234,89± 12,53	234,07± 13,38	182,12± 12,57	301,46± 17,96
LED light	265,52± 16,46*	259,66± 10,50*	265,98± 16,56*	288,76± 12,72*	347,51± 16,88*
Chlorophyll b					
OSRAM L 30W/77 T8 Fluora	204,12± 12,86	203,46± 9,25	158,91± 10,11	167,76± 8,12	174,73± 10,45
LED light	258,62± 11,48*	253,80± 15,20*	183,79± 13,75*	189,64± 11,62*	208,28± 14,25*
Carotenoids					

Lighting treatments	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
OSRAM L 30W/77 T8 Fluora	188,20± 16,53	191,01± 11,99	155,44± 13,85	163,85± 11,21	170,94± 14,37
LED light	229,80± 11,84*	223,09± 16,20*	159,06± 14,94	157,25± 11,07	184,61± 18,16

Notes:
* – significant differences between lighting treatments

Analysis of chlorophyll *a* and chlorophyll *b* content shows that when potato microplants are grown in vitro under optimized spectrum lighting, the chlorophyll content in the leaves is significantly higher compared with fluorescent lamp. Significant differences were determined for all five studied varieties. Increased concentrations of photosynthetic pigments provide better adaptation of meristem potato plants to non-sterile growing conditions in vivo due to a rapid and stable transition to autotrophic nutrition (Belyaeva, 2017). The content of carotenoids significantly increased in plants of Shah and Nevsky varieties. Carotenoids are of keen interest as a non-enzymatic antioxidant defense system. Carotenoids are involved in the quenching of singlet oxygen and peroxide radicals that are generated when chlorophyll is overexcited (Mansour, 2017).

CONCLUSIONS

The influence of the spectral composition of lighting was discovered on the stem length, the leaves and internodes number, photosynthetic pigments content of five potato varieties: Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legend (ripeness group: early). As a result of the study, it was demonstrated that the use of optimized spectrum lighting can lead to an increase in the reproduction rate of potato during in vitro cuttings through the formation of an additional number of internodes and an increase in stem length. The combined influence of lighting factors and genotype (hereditary factor) on morphological parameters was analyzed. It has been determined that the factor of the spectral composition of lighting has the greatest influence on the length of plants and the number of internodes. The fulfilled studies show that when choosing a lighting treatment, it is necessary to assess the specific reaction of the propagated variety to various combinations of the spectrum, since the influence of the heredity factor (variety) contributes to the overall variability of traits no less than the lighting factor. The optimized spectral composition can significantly increase the amount of photosynthetic pigments in meristem potato plants. The research results be used in seed potato production, at the initial breeding stage with growing plants under artificial lighting.

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AGROBIODIVERSITY MANAGEMENT: EXPLORING HOW THE ITALIAN EXPERIENCE CAN HELP PROMOTING NEGLECTED AND UNDERUTILIZED SPECIES IN BURKINA FASO AND NIGER

Maria GONNELLA[1], Francesca BOARI[1], Billy Moussa NEBIE[2], Kabirou MOUDI[3], Jacques NANEMA[2], Sheirita Reine Fanta TIETIAMBOU[4], Lawali DAMBO[3], Iro DAN GUIMBO[3], Filippo ACASTO[5], Hamid EL BILALI[6,*], Rosa Anna SICILIANO[1]

[1]National Research Council (CNR), Bari and Avellino, Italy
[2]Joseph Ki-Zerbo University, Ouagadougou, Burkina Faso
[3]Abdou Moumouni University, Niamey, Niger
[4]University Centre of Gaoua, Nazi BONI University, Bobo-Dioulasso, Burkina Faso
[5]Italian Agency for Development Cooperation (AICS), Ouagadougou, Burkina Faso
[6]International Centre for Advanced Mediterranean Agronomic Studies of Bari (CIHEAM-Bari), Valenzano (Bari), Italy
*Corresponding author: elbilali@iamb.it

ABSTRACT

The project SUSTLIVES (SUSTaining and improving local crop patrimony in Burkina Faso and Niger for better LIVes and EcoSystems), implemented in Burkina Faso and Niger, aims to promote the transition towards sustainable agricultural and food systems more resilient to climate change, ensure food security and improve the livelihoods of rural communities. This transition is driven by the promotion of local agro-biodiversity. Moreover, SUSTLIVES also aims to strengthen the research and innovation capacities of actors in the Agricultural Knowledge and Innovation System (AKIS) on the value chains of neglected and underutilized species (NUS) in Burkina Faso and Niger. To this end, an internship was carried out in March - April 2024 at the National Research Council (CNR) of Italy. The main objective of the internship was to undertake training on agrobiodiversity management and nutritional and functional properties of NUS by addressing, inter alia, the topics of custodian farmers; community seed banks; techniques for multiplication and conservation of genetic resources; agronomic and qualitative characterization of crops; nutritional and functional aspects of NUS and their beneficial health effects; food quality and safety; potential for processing, product development and commercialization. These topics were addressed through lessons, technical visits and discussions with various actors, including farmers growing local varieties and processing companies or associations involved in seed conservation. At the end of the internship, numerous points for reflection emerged. The internship provided insights into (i) organization and support of seed custodian farmers in Burkina Faso and Niger; (ii) development of NUS value chains through raising awareness among stakeholders; (iii) support for all stages in the agri-food

value chain; (iv) creation of a multi-actor framework around the valorisation of certain agricultural products, in particular NUS, in Burkina Faso and Niger.

Keywords: *Agrobiodiversity, NUS, value chain, case study, SUSTLIVES*.

INTRODUCTION

Burkina Faso and Niger are two countries in the sub-Saharan Africa, included in the Sahelian area. They are afflicted by a strong vulnerability due to four major risks identified as 1) climate change, 2) food insecurity; 3) conflicts, and, 4) displacement (Blocher et al., 2022). Mainly climate change and conflicts impact food and livelihood insecurity. In both countries, more than 70% of the population is employed in the agricultural sector and, according to future projections, the Sahelian countries will be affected by repeated cycles of drought and flood. It is expected that the major food crops (viz. maize, rice, millet and sorghum), less resilient to climate change, will show a significant decline in yields in the future decades, with consequent repercussions on food security (Blocher et al., 2022). Aiming to address undernutrition and achieve food security, governments have promoted staple crops (rice, maize) and some cash crops (such as cotton, groundnuts, sesame) by providing seeds, fertilizers and chemicals to farmers through input subsidy programs (Ahmad et al., 2022). The effect of the fertiliser subsidy on target crops (e.g. maize, rice and cotton) was an increase in land allocated to target crops, compared to non-target crops, reducing crop diversity on farms (Ahmad et al., 2022). On the contrary, promoting the sustainable use and conservation of biodiversity within farming systems is relevant to ensure food security and healthy nutrition (greater intake of micronutrients and vitamins) through more stable crop production due to the use of species more adaptable to climate change and resistant to pests and diseases. Finally, crop diversity improves farmers' and rural community's livelihoods by providing production for both direct consumption and additional family income. The shift from subsistence agriculture to a production system that allows income generation passes through the development of value chains based on neglected and underutilised species (NUS) preserved within rural communities. Assessing the potential of these value chains can help building small-scale processing systems and promote economic development.

In this perspective, aiming to pursue these issues, the European Union has recently funded the project SUSTLIVES (SUSTaining and improving local crop patrimony in Burkina Faso and Niger for better LIVes and EcoSystems), a cooperation program started in August 2021 and lasting four years. The project aims at valorising neglected and underutilized crops (NUS), through the strengthening of the research and innovation capacities, the development of inclusive supply chains (particularly of women and young people) and the improvement of national and regional policies to support the sector. A data collection carried out through direct interviews with value chain actors at the national level in both Niger and Burkina Faso, as part of the project SUSTLIVES, highlighted that some common points are relevant for the analysis of the potential development of NUS value chains in the

two countries. In addition, to facilitate access to production inputs (seeds, fertilizers, pesticides), other two points emerged concerning farmers' need to acquire expertise in good practices (organic production or use of technical inputs) and the need to structure the supply of the raw and processed products into cooperatives or groups of villages to facilitate the transportation and marketing of NUS production (SUSTLIVES, 2023a; 2023b).

Conservation programs of biodiversity for food and agriculture have been implemented in several regions of the world. These programs are largely constrained by knowledge gaps, resource limitations and policy weaknesses, consequently, in their implementation they should include management strategies covering research, resource allocation and policy development (FAO, 2022). All these aspects have been applied in European countries through financial support from the Rural Development Program to custodian farmers and farms engaged in conservation and valorisation activities of local agrobiodiversity, developing specific agri-food productions, and research activities. The financial support arrived promptly to save most of the local genotypes held by custodian farmers (so-called 'bio-patriarchs') before their definitive loss. The support of the Rural Development Program, for instance, allowed to maintain some very local Italian agri-food production that would otherwise be at risk of extinction as older farmers died. The complex of factors (several local genotypes preserved from extinction, agronomical and gastronomic traditions, increasing interest and consciousness by consumers for these products) cooperated to create small-scale businesses and diversified resilient and healthy food productions.

In this context, the exchange of experiences and knowledge regarding the Italian agro-biodiversity system, on the one hand, and the Burkinabé/Nigerien one, on the other hand, is useful to strengthen the research and innovation capacities of actors in the Agricultural Knowledge and Innovation System (AKIS). An internship was organized to bring two students from Burkina Faso and Niger to analyse the agro-biodiversity system in some regions of Southern Italy. Complementary training covering all aspects of cultivation, characterization and processing of NUS selected in the framework of the project SUSTLIVE was carried out. This paper describes the organisation and content of the internship and explores how the Italian experience in agrobiodiversity management can help promoting NUS in Burkina Faso and Niger.

MATERIALS AND METHODS

In the framework of the project SUSTLIVES, an internship was organized in Italy as a result of collaboration between the National Research Council (CNR, www.cnr.it), the Joseph KI-ZERBO University of Burkina Faso and Abdou Moumouni University of Niamey, Niger. The internship took place at two institutes of CNR, namely, at the Institute of Sciences of Food Production (ISPA, https://www.ispacnr.it) in Bari and the Institute of Food Sciences (ISA, www.isa.cnr.it) in Avellino. These research institutes have well-established interdisciplinary and complementary expertise in several issues in the field of food

quality and safety. The internship was organized for two interns, one from each University, and completely founded by the project SUSTLIVES.

The internship was implemented according to the principle of a training of trainers, providing the participants with case studies, examples and instruments to be transferred to other stakeholders (students, researchers, extension workers, farmers and value chain actors) during the training sessions and workshops to be held in Burkina Faso and Niger.

In this light, the interns were selected by the two Universities to choose persons with the most appropriate scientific background to fully understand the topics of the internship and properly transfer these experiences to the stakeholders of their countries. Before the internship period, a program was scheduled that listed the activities to be carried out through lessons, laboratory training, technical visits and discussions with various actors (farmers, processing entrepreneurs, associations) in the field. The internship of six weeks was planned, and the interns were going to spend four weeks at the Institute of Sciences of Food Production (ISPA) in Bari and two weeks at the Institute of Food Sciences (ISA) in Avellino.

The contents of the internship included the following topics: custodian farmers; community seed banks; techniques of multiplication and conservation of genetic resources; agronomic, morphological and qualitative characterization of plant species; nutritional, functional and healthy features of NUS; food security; food quality and safety; potential processing, product development and marketing. The contents of the internship were selected to fulfill the specific objectives of Activity 2.2 (Training and capacity building of actors in the value chain) of the project SUSTLIVES. However, the topics of the internship were of great interest also for other project activities: Act. 1.2: Identification of guardian farmers, community gene banks and good practices; Act. 1.3: Access, selection, multiplication and distribution of target stress-tolerant NUS seeds; Act. 1.5: Exchange of knowledge and information between stakeholders; 2.1: Participatory analysis of value chains and markets of priority stress-tolerant NUS.

The administrative organization of the internship was carried out mainly through the drawing up and signing of an internal agreement between the CNR and the Universities of Burkina Faso and Niger, and the signing of an invitation letter to the beneficiaries of the internship.

RESULTS AND DISCUSSION

The intern from the Joseph Ki-Zerbo University of Burkina Faso is Mr. Nebie Billy Moussa, an economist specializing in agricultural economics, natural resources and environment, a specialist in project management and a master's student at the end of the Master's cycle in Innovation and Development in rural areas of the AGRINOVIA program. He is responsible for the Program of the Association of Professionals in Private Irrigation and Related Activities (APIPAC). The intern from the Abdou Moumouni University of Niamey, Niger, is Mr. Moudi Kabirou, a specialist in plant protection and improvement of Sahelian agrarian systems, a doctoral student in the second year of his thesis on the theme: Optimization of the

productivity of the cultivation of cassava and sweet potato to improve the resilience of the rural population of Niger. Moudi Kabirou also works at the Federation of market gardening cooperatives of Niger (FCMN Niya) with more than 42,000 producers from all regions of Niger.

Based on the expertise of the two CNR institutes, the activities developed at ISPA concerned the management of agro-biodiversity, seed conservation systems, agronomic, qualitative and nutritional characterization of the selected NUS in the project SUSLIVES, food safety, product processing perspectives; the activities developed at ISA concerned the main problems of human nutrition and the nutritional value of NUS in relation to the improvement of the diet quality in Burkina Faso and Niger, the nutritional, functional and healthy features of the NUS of interest, with reference to specific groups of nutrients and bioactive compounds and through a specific laboratory activity of analysis carried out on okra, one of the selected NUS.

One of the objectives of the internship was to allow trainees to draw inspiration from the practices applied by value chain actors in Italy to co-construct with the actors of Niger and Burkina Faso possible solutions around the issues of developing the value chains of the main NUS selected by the project SUSTLIVES. Considering this aim, the technical and field visits had a great impact in the experience of the internship due to the discussion about the topics listed above and to the observation of different situations with high value as case studies to be transferred. Visits to farmers' organizations in Italy revealed innovative strategies to address agricultural challenges and enhance biodiversity. Two case studies stand out for their effectiveness in integrating research, collaborations and sustainability. The local association “Salento Km0” (Zollino, Lecce) involves over 40 farmers, municipal authorities and universities for the development of local crops. Among these, the "Pisello Nano" (dwarf pea) has been characterized by its nutritional values and its historical identity. Now exported to the United States, it represents an example of synergy between municipal bodies, universities and farmers to enhance local products at risk of extinction. The visit to the ‘seed guardian’ Angelo Giordano highlighted the global commitment to seed protection. In fact, seed reproduction and exchanges between seed savers are fundamental. Moreover, some local genotypes, saved by Giordano and other seed savers, do not require much water for production and for centuries farmers in Southern Italy have developed a specific technical practice that is potentially crucial for horticulture in these regions, traditionally affected by scarcity of water. This constitutes a wealth of knowledge that can animate an effective exchange of experiences and expertise between Southern Italy and the Sahel countries afflicted by the climate crisis. These cases demonstrate how collaboration, together with innovation, can create added value in agricultural activities, promoting the survival of local products and biodiversity.

Other field excursions to Italian agricultural companies provided interesting insights into challenges and solutions related to agricultural production in complex contexts. Three companies stood out for their innovation and commitment to

sustainability. The farm 'Terzeria' in Villapiana, Calabria, extends over 400 hectares, cropped with rice, citrus fruits and vegetables, has the main challenge of finding the right solution to face soil salinity due to its location below sea level and to the constitutional nature of its soils and the sediments from which they originate. Collaborations with universities and research institutes made soil improvement techniques through improving soil microbial activity and the utilization of specific crops and cultivars in a circular economy conduction with solar panels for irrigation and management of greenhouses and a plant to compost urban waste to increase the soil organic matter. The commitment to social projects of the 'Semi di Vita' cooperative (Bari, Apulia region) is another example of a case study under the philosophy of organic production, of fruit and vegetables, with progressively increasing surfaces, and the production of eggs from laying hens. The last case is the "Colle di Seta - Agricola Cantatore" company in Ruvo (Bari, Apulia region), with a family-run business integrating scientific research into product processing, obtaining the development of innovative food products, very appreciated on the market. These case studies show the way of tackling environmental, social and market challenges, contributing to the growth of a sustainable and cutting-edge sector, without neglecting local traditions, which could be a topic of discussion between the countries involved in the project SUSTLIVES.

The internship allowed the interns to discuss several issues related to the improvement of value chains of NUS and seed systems in Burkina Faso and Niger. The following critical points were defined: (i) difficult access to quality seeds and propagation material; (ii) low agronomic skills and knowledge of farmers; (iii) low performance; (iv) variation in product quality; (v) lack of appropriate storage/packaging infrastructure; (vi) limited processing knowledge; (vii) disorganized or non-existent value chain and market; (viii) discouragement of investment due to low market value; (ix) high consumer prices due to lack of economy of scale; (x) low consumption in production areas (El Bilali et al., 2023).

The exchange of knowledge during the internship allowed to foresee that a better organization of seed producers could improve access and reproduction of quality seeds for the benefit of stakeholders. The integration of Burkinabè and Nigerien seed guardian organizations into international networks could improve agronomic skills and yields. Intensifying advocacy by agricultural organizations could greatly contribute to establishing a legislative environment conducive to the promotion of biodiversity and better consideration of local seeds in public policies and agricultural development strategies. This could encourage investments and improve storage infrastructure. The creation of economies of scale around plant species could contribute to the development of significant and sustainable value chains around these NUS.

Moreover, promoting the consumption of these NUS through better marketing around their important nutritional and functional values could boost the consumption of these products, which have already started to take a significant part in urban populations and especially the very popular middle class, based on the quality of food and its origin. The proper consumption of these NUS could also

play a central role in alleviating malnutrition problems, as they represent a rich source of micronutrients, such as vitamins and minerals, and bioactive molecules, such as antioxidant compounds, that can positively affect human health, especially among city dwellers. According to Bricas et al. (2014) more than 60% of urban dwellers in Africa suffer from malnutrition. So, increasing the awareness of the importance of vegetable consumption in fighting malnutrition and, more generally, food insecurity problems could prompt the vegetable market and the development of a sustainable value chain thus providing employment opportunities, especially for unemployed women and young people. The development of niche markets through awareness raising among certain key players could help to strengthen the sustainability of the value chains of NUS. This is the case of amaranth grains in the manufacture of gluten-free bread for the benefit of diabetics, the number of whom has been increasing in Burkina Faso (WHO, 2016). The same is true for the use of okra in bread making, roselle seeds in cosmetics and medicine, moringa seeds in medicine.

To sum up, this internship was a real opportunity to bring together the practices of Italian, Burkinabè and Nigerien actors, with the aim of making them mutually feed on their knowledge, for the benefit of agriculture that is more respectful of biodiversity and creates sustainable opportunities.

CONCLUSIONS

The internship – carried out in Italy from March 10 to April 18, at the Institute of Sciences of Food Production (ISPA) in Bari and at the Institute of Food Sciences (ISA) in Avellino, both institutes of the National Research Council of Italy (CNR) – made it possible to deepen the trainees' knowledge on biodiversity and the nutritional and functional properties of NUS. Above all, it showed the need of good practices that could contribute to the improvement of sustainable practices of biodiversity conservation and the roles of actors and stakeholders in Burkina Faso and Niger: (i) The organization and the support of farmer seed guardians; (ii) the development of NUS value chains through awareness-raising and advocacy among different stakeholders; (iii) the support for the links in production towards the processing of agricultural products; (iv) the creation of a multi-actor framework around the valorisation of certain agricultural products, particularly the NUS. These issues will fuel the co-construction of solutions adapted to the realities of Burkina Faso and Niger. The internship highlighted that establishing multi-stakeholder frameworks involving researchers, farmer organizations, public authorities, local communities, and other actors can be key to valorise local products and creating sustainable value chains. In Burkina Faso, such frameworks could promote and enhance typical regional products like “Fabirama de Arbolé” and “Chitoumou” (caterpillars from the Hauts Bassins region), as realized in Italy for Zollino’s “Pisello Nano”. Finally, encouraging collaboration between businesses and scientific research, supported by advocacy efforts from projects, programs, farmer organizations, and civil society, is essential in order to initiate the sustainable development of the NUS value chains in Burkina Faso and Niger.

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UREASE ACTIVITY OF EDAPHOTOPES ON ROCK DUMPS OF COAL MINES OF THE DONETSK PEOPLE'S REPUBLIC

Andrey BEREZOVSKIY*, Dmitry SYSCHIKOV, Irina AGUROVA

Federal State Budgetary Scientific Institution "Donetsk botanical garden", Donetsk, DPR, Russia
*Corresponding author: berezovskiias@list.ru

ABSTRACT

The aim of this work is to study the influence of phytorecultivation measures on changes of urease activity of edaphotopes at coal mine dumps of the Donetsk People's Republic. To study urease activity, monitoring sites were selected in the territories of coal mine dumps of varying degrees of degradation. To assess the influence of monospecies herbaceous phytocenoses on the course of soil-forming processes in edaphotopes of anthropogenically transformed ecosystems, seeds of *Kitaibelia vitifolia* Willd., *Onobrychis arenaria* (Kit.) DC. were sown. The research was carried out throughout 2021. Analysis of the data obtained showed that urease is confined to underlying genetic horizons, which is explained by the shortening of the soil profile and the leaching of soluble ammonium salts from the upper horizons. The study of the seasonal dynamics of the intensity of enzyme functioning showed a parabolic nature of changes in enzymatic activity with a minimum in the summer period of research and a maximum in the spring, during the period of enrichment of the soil with organic residues of the previous growing season. Sowing plants in monitoring areas had a positive effect on the processes of initial soil formation. Thus, when using *Onobrychis arenaria*, urease activity increased on average by 18-104% due to the fixation of atmospheric nitrogen by legumes, while in the variants of experiments using *Kitaibelia vitifolia* its activity increased by only 9-64%.

Keywords: *dumps, enzymes, phytorecultivation, soil, technogenous ecosystems, urease.*

INTRODUCTION

The acceleration of the pace of technogenesis and a significant increase in the number of anthropogenic objects polluting the environment certainly has a negative impact on natural landscapes. Extraction and processing of rock mass and rocks through mining leads to the alienation of significant areas for rock dumps, which, in turn, require recultivation. One of the effective and inexpensive methods of eliminating the harmful effects of man-made objects, in particular coal mine dumps, on the environment is phytorecultivation. Currently, there is a process of intensive improvement of recultivation methods not only from the point of view of

environmental protection, but also economic efficiency (Syschikov et al., 2020). Soils of technogenic ecotopes belong to a special category of soils, which only in a number of characteristics can resemble real soils. Phytorecultivation is a mechanism that makes it possible to bring the soil conditions of technogenic ecotopes closer to the conditions of natural landscapes (Agurova and Syschikov, 2021).

When studying the influence of monospecific communities of *Kitaibelia vitifolia* Willd. and *Onobrychis arenaria* (Kit.) DC. pH indicators of edaphotopes of coal mine dumps show the prospects of using phytomeliorants in the conditions of technogenic ecotopes to change the reaction of the environment (toward slightly acidic or neutral), which in turn will improve the availability of mineral nutrition elements and help expand the list of plant species used for reclamation (Agurova and Syschikov, 2021). In addition, when carrying out a number of phytorecultivation works, it was established that the prevailing trend is an increase in the concentration of mineral nitrogen compounds in the soil (Syschikov at al., 2021), a positive effect was established with the influence of plants of the Poaceae on the content of organic matter (Syschikov and Agurova, 2020).

The enzymatic activity of soil is one of the main indicators of its fertility. Any soil is characterised by a certain level of enzymatic activity, determined by the diversity and quantitative content of enzymes (Shvakova, 2013). Soils that are constantly experiencing significant anthropogenic impact are characterised by a changed qualitative and quantitative composition of microorganisms; tend to reduce biological activity, which leads to the transformation of biogeochemical cycles of nutrients A number of authors have shown that enzymatic activity reflects the direction and intensity of the processes of biochemical transformations occurring in the soil (Holik et al., 2019; Utobo, Tewari, 2015; Wang et al., 2015).

The activity of soil enzymes is used as a diagnostic criterion of soil fertility, and changes in enzyme activity indicate anthropogenic impact. Enzymes demonstrate high stability during long-term storage; this fact, as well as the low experimental error, contribute to the use of enzymatic activity parameters as a diagnostic indicator of soil condition (Shorec and Balaeva-Tihomirova, 2018).

A number of scientific works, including dissertations, are devoted to the study of the enzymatic activity of soils. Thus, at the Faculty of Forestry and Wood Technology at Mendel University in Brno, Czech Republic, research is being carried out to study the enzymatic activity of soil after long-term use of inorganic and organic fertilizers (Holik et al., 2019). The participation of soil enzymes in the transformation of organic compounds into forms that are easily absorbed by plants, as well as their participation in metabolic processes that occur in the soil, was studied by American scientists (Martinez et al., 2021). The effect of soil fraction size on the activity of soil enzymes was investigated. The Faculty of Natural Resources and Soil Sciences at the University of Gondar, Ethiopia, has also addressed the issue of restoring degraded soils (Fentie et al., 2020).

Urease is an enzyme that catalyses the hydrolysis of urea into CO_2 and NH_3 with a reaction mechanism based on the formation of carbamate as an intermediate. The

ammonium cation NH_4^+ formed as a result of the urease reaction is a direct source of nitrogen nutrition for plants, therefore urease activity is one of the most important indicators of biological activity and soil quality (Povolockaja, 2020; Utobo, Newari, 2015).

The aim of this work is to study the influence of phytorecultivation measures on changes of urease activity of edaphotopes at coal mine dumps of the Donetsk People's Republic.

MATERIAL AND METHODS

To study urease activity, monitoring sites were selected in the territories of coal mine dumps of varying degrees of degradation. When choosing them, factors such as the prevalence of the type of disturbance within the study site, the degree of anthropogenic transformation, the possibility of restoring biological productivity and involvement in economic activity, and the potential environmental effect when carrying out reclamation activities were taken into account. To assess the influence of monospecies herbaceous phytocenoses on the course of soil-forming processes in edaphotopes of anthropogenically transformed ecosystems, seeds of *Kitaibelia vitifolia* Willd., *Onobrychis arenaria* (Kit.) DC. were sown on an area of 1 m^2 separately at each of the monitoring sites.

Based on the results of the studies, it has been shown that the soils of rock dump ecosystems are characterized by a strongly acidic or acidic reaction of the environment (pH varies depending on the horizon and site in the range from 4.06 to 4.92), which complicates the process of colonizing the dump with plants. According to this indicator, the worst conditions develop on the slopes of the dumps, while in the zone of flattening of the dump slope the reaction of the environment is slightly alkaline (pH 7.02) (site No 2).

In terms of organic matter content, we classify the zonal soil as moderately humified (3.38%), all soils in rock dump ecosystems are characterized by a low humus content, not exceeding 0.45%, and therefore we classify it as very weakly humified. The humus-accumulative horizon of zonal soil (site No 1) is characterized by a high supply of mobile phosphates (18.45 mg/100 g of soil). Ecosystems of coal mine dumps are characterized by very low and low contents of available phosphorus (the amount varies from 0.63 to 3.63 mg/100 g of soil). The humus-accumulative horizon of the control plot is characterized by an increased content of exchangeable ammonium (5.75 mg/100 g of soil). For rock dump ecosystems, the supply of ammonium nitrogen is very low (the range of variation in its amount is from 0.97 to 2.61 mg/100 g of soil). Only the humus-accumulative horizon of site №1 is characterized by a high content of nitrate nitrogen (3.3 mg/100 g of soil). For rock dump ecosystems, the supply of nitrate nitrogen is very low—the content does not exceed 0.5 mg/100 g of soil.

The research was carried out throughout 2021 (spring, summer, autumn). Soil samples were selected according to genetic horizons (Zvjagincev, 1991) from localities with natural vegetation cover and in places of experimental sowing of

phytorecultivators a year after sowing. The description of soil sections was carried out according to generally accepted methods (Rozanov, 1983).

Monitoring site No 1. The adjoined territory to the southern part of the dump of mine № 12 "Naklonnaya" (Proletarsky district, Donetsk). Total projective coverage 95-100%. *Elytrigia repens* (L.) Desv. and *Vicia cracca* L. growing in groups are dominated. *Artemisia absinthium* L., *Verbascum lychnitis* L., *Achillea pannonica* Scheele, *Euphorbia virgata* Waldst & Kit. are found scatteredly. *Linaria vulgaris* L. and *Pilosella echioides* (Lumn.) F. Schult & Sch. Bip are grown singly. Of the ephemerals, the following species are noted: quite a lot of *Holosteum umbellatum* L. and scattered *Lepidium perfoliatum* L.

Section No 1. Medium-humused ordinary chernozem usual.

A_1, 0-47 cm – fresh, dark brown, homogeneous, light loamy, medium-grained, moderately thick. No inclusions are noted. There are lots of roots. The transition to horizon A_2 is clear in color and structure.

A_2, 47-86 cm – fresh, light chestnut brown, heterogeneous, light loamy, medium-grained, moderately dense. No inclusions are noted. The roots are rare. The transition to horizon B is abrupt in color and structure.

B, 86-110 cm – dryish, light maroon color, homogeneous, loamy, lamellar, moderately thick. No inclusions are noted. Sporadic roots. Transition to horizon C tongue-like in color.

C, deeper than 110 cm – dryish, brownish-orange, homogeneous, loamy, lamellar, thick. No inclusions are noted. There are no roots.

We consider this site as a nominal control.

Monitoring site No 2. Zone of flattening of the slope of southern exposure at the base of the coal rock dump of the Lenin mine (Gornyatsky district, Makeevka). The phytocenosis is represented by *Echium vulgare* L., *Sideritis montana* L., *Stachys transsilvanica* Schur, *Anisantha tectorum* (L.) Nevski, *Calamagrostis epigeios* (L.) Roth, *Poa compressa* L., *P. bulbosa L.*, *Galium humifusum* M. Bieb., *Daucus carota* L., *Achillea pannonica*, *Artemisia absinthium*, *A. austriaca Jacq.*, *Centaurea diffusa* Lam., *Senecio vernalis* Waldst. & Kit.,, *Linaria maeotica* Klokov, *Phragmites australis* (Cav.) Trin. ex Steud., the total projective cover is 50-60%, there are clearings that are not overgrown, the dominance of individual species is not expressed, among woody plants, in addition to the recultivator *Robinia pseudoacacia* L., self-seeding *Fraxinus pennsylvanica* Marsh, *Acer negundo* L., *Ulmus pumila* L. is present in this area, *Juglans regia* L.

Section No 2. Primitive sedimentary undeveloped soils.

A, 0-10 cm – brown, relatively compacted, fine-grained, dryish. Rockiness – 5%. Densely permeated with plant roots.

C – dark grey, metamorphosed shale, lamellar, dry, penetrated by plant roots. Rockiness – 30%. Traced to a depth of 30 cm.

Monitoring site No 3. Lenin mine dump slope with southern exposure (Gornyatsky district, Makeevka). *Echium vulgare* dominates; *Picris hieracioides* L., *Senecio vernalis*, *Linaria maeotica*, *Reseda lutea* L., *Oberna behen* (L.) Ikonn. are also represented; among the woody plants in the area surrounding the site,

Robinia pseudoacacia, *Acer negundo*, *Juglans regia* are found sporadically in the sample site.

Section No 3. Substrate with signs of soil formation.

A, 0-15 cm – brown, loose, fine-grained, dryish. Rockiness – 5%. The transition to the C horizon is gradual, with streaks in color.

C – fawn, traced to a depth of 30 cm. Rockiness – 15%. Salt efflorescence and shale metamorphization products are present.

Monitoring site No 4. Slope of the dump of mine № 12 "Naklonnaya" of eastern exposure (Proletarsky district, Donetsk). Monospecific group *Oberna behen*. The total projective coverage is 10-15%.

Section No 4. Primitive undeveloped fragmentary soils.

A, 0-27 cm – dry, dark grey, homogeneous, structureless, powdery, loose. No new growths are noted, stone content is 10%. The transition to horizon C is unclear in color.

C – dry, dark brown, homogeneous, structureless, powdery, loose. No new growths are noted, stone content is 50%. Sporadic roots. Traced to a depth of 60 cm.

In the profile, primary aggregation along plant roots is observed; the accumulation of humus has no morphological expression due to the weak development of the clay component. The existing humus is "camouflaged" by the grey color of the crushed rock.

Monitoring site No 5. The slope of the dump of mine № 12 "Naklonnaya" of northern exposure (Proletarsky district, Donetsk). The total projective coverage is 25-30%. Quite a lot of *Echium vulgare*, Oenothera biennis L., *Ambrosia artemisiifolia, Artemisia absinthium, Daucus carota, Centaurea diffusa, Linaria genistifolia* (L.) Mill., *Holosteum umbellatum* and *Senecio vernalis* grow scatteredly, *Rumex crispus* L. and annual shoots of *Acer negundo* are found sporadically. *Achillea pannonica* and *Chondrilla juncea* L. are added to the lower part of the site.

Section No 5. Primitive undeveloped soils.

A – 0-20 cm. Fresh, dark brown, homogeneous, structureless, powdery, loose. No new growths are noted, stone content is 25%. Densely permeated with plant roots. The transition to horizon C is clear in color.

C – dryish, dark grey, homogeneous, structureless, powdery, loose. No new growths are noted, stone content is 40%. Sporadic roots. Traced to a depth of 45 cm.

Determination of urease activity was carried out according to K.Sh. Kazeev (Kazeev et al., 2003). Statistical processing of experimental data was carried out using generally accepted methods of parametric statistics at a 5% significance level (Pryseds'kyj, 1999).

RESULTS AND DISCUSSIONS

Analysis of urease activity in edaphotopes of anthropogenically transformed ecosystems in the spring period of research showed an ambiguous picture of its distribution along the soil profile. Thus, in the genetic horizons of the slope of the

Lenin mine dump (sites No 2-3), the urease activity in the parent rock was 1.5-3 times higher than the similar indicators of the humus-accumulative horizon (Table 1).

Table 1. Urease activity (mg NH_3/10 g soil per day) in soils of monitoring sites in spring

Site, horizon	Non-reclamed		Reclamed	
	M±m	%	M±m	%
№ 2 Ao	0.65±0.09*	30.7	0.89±0.06*	42.0
№ 2 Co	1.98±0.08*	618.8	2.63±0.03*	821.9
№ 2 Ak	0.65±0.09*	30.7	0.74±0.04*	34.9
№ 2 Ck	1.98±0.08*	618.8	2.21±0.03*	690.6
№ 3Ao	0.68±0.09*	32.1	0.88±0.07*	41.5
№ 3 Co	1.04±0.23*	325.0	1.39±0.06*	434.4
№ 3 Ak	0.68±0.09*	32.1	0.77±0.05*	36.3
№ 3 Ck	1.04±0.23*	325.0	1.15±0.06*	359.4
№ 4 Ao	0.45±0.06*	21.2	0.61±0.05*	28.8
№ 4 Co	0.24±0.05	75.0	0.31±0.07	96.9
№ 4 Ak	0.45±0.06*	21.2	0.52±0.05*	24.5
№ 4 Ck	0.24±0.05	75.0	0.27±0.08	84.4
№ 5 Ao	1.90±0.04*	89.6	2.56±0.03*	120.8
№ 5 Co	1.90±0.10*	593.8	2.43±0.08*	759.4
№ 5 Ak	1.90±0.04*	89.6	2.18±0.11	102.8
№ 5 Ck	1.90±0.10*	593.8	2.15±0.09*	671.9
№1 A	2.12±0.03			
№ 1 C	0.32±0.03			

Here and in Tables 2–3: % - is the percentage of values exceeding those of similar soil horizons in site No 1, * - the differences are statistically significant at $p < 0.05$, o – plantings of *Onobrychis arenaria*, k – plantings of *Kitaibelia vitifolia*, % – percentage of excess

In the technozems of the remaining monitoring sites, the predominant trend was the intensification of enzymatic processes of ammonium accumulation within the upper horizon, leading in some cases to the achievement of enzymatic activity values in zonal soil. This fact can be explained by the extremely weak development of the upper soil horizon, the degree of formation of the phytocenosis and microbiocenosis, as well as the characteristics of the rocks that form these technogenic elements. The shortened soil profile and the relatively high biological activity of the underlying layer also cause an excess of urease activity in the C horizon to be 3-8 times higher in most monitoring sites compared to similar indicators in zonal soil (Table 1).

Sowing various crops at the monitoring sites had a positive effect on the processes of transformation of nitrogen compounds, which, in particular, can be judged by the level of enzymatic activity. Thus, the use of *Onobrychis arenaria* in the experiment led to an intensification of urease functioning in spring by 29-36%

compared to similar genetic horizons in areas with natural vegetation (Table 1). This established fact may be due to the fact that legumes have an effectively functioning rhizosphere symbiosis with nodule bacteria that actively absorb atmospheric nitrogen. A significant excess of the control level in the C horizon can be explained by the fact that the primitive soils of the studied monitoring sites have an underdeveloped soil profile of low thickness, poorly differentiated into horizons. When *Kitaibelia vitifolia* was used as a phytomeliorant, the degree of severity of its positive effect on the functioning of the studied enzyme was less pronounced, amounting to 11-16% compared to areas with natural vegetation cover. Along with this, the distribution of urease activity over the soil horizons of the monitoring plots was practically no different from the experimental variants in plots without sowing plants (Table 1).

In summer, we noted a statistically significant decrease in urease activity compared to the values obtained in the spring. Thus, in areas with natural vegetation, urease activity decreased by 27-70% in horizon A and by 17-68% in horizon C (Table 2).

Table 2. Urease activity (mg NH_3/10 g soil per day) in soils of monitoring sites in summer

Site, horizon	Non-reclamed		Reclamed	
	M±m	%	M±m	%
№ 2 Ao	0.37±0.03*	23.0	0.49±0.05*	30.4
№ 2 Co	0.43±0.07*	45.7	0.57±0.06*	60.6
№ 2 Ak	0.37±0.03*	23.0	0.42±0.05*	26.1
№ 2 Ck	0.43±0.07*	45.7	0.47±0.05*	50.0
№ 3Ao	0.56±0.03*	34.8	0.77±0.08*	47.8
№ 3 Co	0.63±0.05*	67.0	0.81±0.05	86.2
№ 3 Ak	0.56±0.03*	34.8	0.64±0.03*	39.8
№ 3 Ck	0.63±0.05*	67.0	0.69±0.04*	73.4
№ 4 Ao	0.40±0.04*	24.8	0.53±0.03*	32.9
№ 4 Co	0.30±0.05*	31.9	0.39±0.03*	41.5
№ 4 Ak	0.40±0.04*	24.8	0.46±0.05*	28.6
№ 4 Ck	0.30±0.05*	31.9	0.33±0.05*	35.1
№ 5 Ao	0.33±0.04*	20.5	0.42±0.03*	26.1
№ 5 Co	0.20±0.03*	21.3	0.26±0.04*	27.7
№ 5 Ak	0.33±0.04*	20.5	0.37±0.03*	23.0
№ 5 Ck	0.20±0.03*	21.3	0.23±0.02*	24.5
№ 1 A	1.61±0.08			
№ 1 C	0.94±0.07			

A similar trend was noted in the genetic horizons of model plots where experimental planting was carried out. In our opinion, the data obtained can be explained not only by more severe edapho-climatic conditions during this period of research, but also by a decrease in the activity of microbiological transformation of organic matter with the release of nitrogen-containing compounds and their active absorption by plants during the growing season. The highest phytoremediation

effect was observed in monitoring areas with *Onobrychis arenaria seeded*, which was expressed in an increase in urease activity by 27-38% relative to areas with natural vegetation cover. Along with this, when using *Kitaibelia vitifolia*, not only a minimal positive effect on enzymatic activity was recorded (an increase of 9-15%), but also a decrease in its relative values in similar experimental variants compared to the spring period.

During the autumn period of research, a restoration of urease activity values to the level noted during spring sampling was recorded in the genetic horizons of soils of almost all studied monitoring sites (Table 3).

Table 3. Urease activity (mg NH_3/10 g soil per day) in soils of monitoring sites in autumn

Site, horizon	Non-reclamed		Reclamed	
	M±m	%	M±m	%
№ 2 Ao	0.60±0.05*	30.3	0.71±0.06*	35.9
№ 2 Co	1.89±0.09*	343.6	2.00±0.03*	363.6
№ 2 Ak	0.60±0.05*	30.3	0.55±0.04*	27.8
№ 2 Ck	1.89±0.09*	343.6	2.05±0.03*	372.7
№ 3Ao	0.63±0.03*	31.8	0.59±0.07*	29.8
№ 3 Co	0.95±0.11*	172.7	1.13±0.06*	205.5
№ 3 Ak	0.63±0.03*	31.8	0.77±0.05*	38.9
№ 3 Ck	0.95±0.11*	172.7	1.15±0.06*	209.1
№ 4 Ao	0.43±0.03*	21.7	0.61±0.05*	30.8
№ 4 Co	0.31±0.07*	56.4	0.31±0.07*	56.4
№ 4 Ak	0.43±0.03*	21.7	0.52±0.05*	26.3
№ 4 Ck	0.31±0.07*	56.4	0.27±0.08*	49.1
№ 5 Ao	0.85±0.05*	42.9	1.56±0.03*	129.3
№ 5 Co	0.70±0.13	127.3	1.43±0.08*	441.9
№ 5 Ak	0.85±0.05*	42.9	1.18±0.11	110.1
№ 5 Ck	0.70±0.13	127.3	1.15±0.09*	390.9
№1 A	1.98±0.05			
№1 C	0.55±0.09			

However, in the soils of site No 5, the noted trend was not so pronounced, which, in our opinion, is due to harsh hydrothermal conditions and underdeveloped plant communities (monospecific group *Oberna behen*).

The sowing of phytomeliorants had a beneficial effect on changes in the activity of urease in the soils of almost all genetic horizons of the monitoring sites. Maximum values of enzymatic activity, exceeding similar values in most areas with natural vegetation cover by 19-104%, were noted in variants of experiments using *Onobrychis arenaria*.

CONCLUSIONS

Analysis of the data obtained showed that urease is confined to underlying genetic horizons, which is explained by the shortening of the soil profile and the leaching

of soluble ammonium salts from the upper horizons. The study of the seasonal dynamics of the intensity of enzyme functioning showed a parabolic nature of changes in enzymatic activity with a minimum in the summer period of research and a maximum in the spring, during the period of enrichment of the soil with organic residues of the previous growing season. Sowing plants in monitoring areas had a positive effect on the processes of initial soil formation. Thus, when using *Onobrychis arenaria*, urease activity increased on average by 18-104% due to the fixation of atmospheric nitrogen by legumes, while in the variants of experiments using *Kitaibelia vitifolia* its activity increased by only 9-64%.

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APPLICATION OF CHITOSAN IN THE CONTROL OF ECONOMICALLY IMPORTANT PHYTOPATHOGENIC FUNGI

Jelena EĆIMOVIĆ, Slavica VUKOVIĆ, Sanja LAZIĆ, Dragana BOŠKOVIĆ, Aleksandra ŠUŠNJAR, Dragana ŠUNJKA*

University of Novi Sad, Faculty of Agriculture, Trg Dositeja Obradovića 8, Novi Sad, Serbia
*Corresponding author: dragana.sunjka@polj.edu.rs

ABSTRACT

Agricultural producers face numerous challenges today. They must strive to achieve high yields to meet the food demands of the population, while also ensuring the safety of the food. Due to the development of resistance in targeted organisms and the adverse effects chemical pesticides pose to human health and the environment, it is necessary to seek eco-friendly methods for pest control. Chitin is the second most abundant biopolymer on earth, after cellulose. Its deacetylated derivative, chitosan, has some beneficial characteristics that give it the potential to become a biopesticide. Phytopathogenic fungi are a limiting factor in agricultural production, causing significant economic losses. Many researchers have confirmed the fungicidal activity of chitosan and it is progressively asserting its role in integrated pest management. It has different modes of action, such as cell membrane/cell wall disruption, interaction with the DNA of microorganisms, chelation of nutrients necessary for microorganisms, film formation and induction of host plant defense mechanism. *In vitro* studies have shown that chitosan treatment leads to inhibition of mycelial growth, sporulation, and spore germination of phytopathogenic fungi. It also induces morphological alterations in hyphae and spores and influences the production of fungal virulence factors. Chitosan is applied foliarly, to seed, and as a soil enhancer. Extensive research on the synergistic effects of a mixture of chitosan and conventional fungicides shows potential for reducing the usage of chemical pesticides while effectively controlling pathogens.

Keywords: *chitin, chitosan, fungicides, phytopathogenic fungi, biopesticides.*

INTRODUCTION

The expanding global population demands intensive agriculture, which requires the extensive application of pesticides. Agricultural producers today face many obstacles. Using synthetic pesticides often leads to negative consequences for the environment and human health. In addition, the intensive and improper application of these chemicals makes it difficult to control the target organisms, through the

development of resistant populations of pests, which creates high production costs and doesn't obtain satisfactory yields. A large number of active substances are prohibited for use, and the possibilities for producers to effectively control pests are reduced. To lower the negative impact and usage of chemical pesticides to a minimum, the research on biological agents in plant protection has increased.

Chitin, a polymer of N-acetyl glucosamine, is the second most abundant polysaccharide in nature, after cellulose. Its limited solubility in water restricts its usage. The characteristics of its deacetylated derivative, chitosan, such as biological activity, non-toxicity to non-target organisms, biodegradability and biocompatibility, make it suitable for use as a biological plant protection agens (Hassan and Chang, 2017).

Research on chitosan as a potential plant protection agent began in the second half of the 20th century. Since then, many papers about the effect of chitosan on various phytopathogenic organisms and pests have been published.

CHITIN AND CHITOSAN

The name chitin originates from the Greek word for armor – *chiton*, because it acts as structural support and protective material for invertebrates. Its role is constructive, it gives strength to the body (holds calcium carbonate in a solid composite structure), and it also serves as a storage of carbohydrates and nitrogen. It is present in the exoskeleton of invertebrates, as well as in the cuticle of insects, and is the main structural polymer in the cell wall of fungi (Crini, 2019).

The history of chitosan begins in 1859 with the work of Charles Rouget (Morin-Crini et al., 2019), who found chitosan as a component of the cell wall of some fungi, such as *Mucor rouxii* and fungi from the *Zygomycetes* class (Janjić, 2010). The name chitosan was introduced in 1894 by Felix Hoppe-Seyler for a chitin derivative soluble in acids, obtained by treating the shells of crabs, scorpions and spiders (Crini, 2019).

Chitosan is a linear polysaccharide, a derivative of chitin with a low degree of acetylation (less than 50 %) (Hromiš, 2015). It consists of 2-amino-2-deoxy-β-D-glucopyranose and 2-acetamido-2-deoxy-β-D-glucopyranose units interconnected by β-(1→4) glycosidic bonds (Figure 1) (Morin-Crini et al., 2019).

Figure 1 Chemical structure of chitin (left) and chitosan (right) (Morin-Crini et al., 2019)

Thanks to a series of positive characteristics such as its cationic nature, biodegradability, biocompatibility, biological activity, adhesiveness, as well as

compatibility with other substances, chitosan has been intensively researched in recent decades (Janjić, 2010). Chitosan is biodegradable under the influence of enzymes from various sources, including chitinases, cellulases and hemicellulases, proteases and lipases that are widely distributed in nature, and is considered safe for humans, animals and the environment (Hromiš, 2015). It adheres well to plant surfaces, forming a protective barrier against pests and pathogens (El Hadrami et al., 2010). It can be formulated with other natural compounds or pesticides to improve their effectiveness or provide a controlled release (Maluin et al., 2020).
The largest resource for chitin and chitosan production is biowaste from the marine industry (Morin-Crini et al., 2019). The main producer of chitosan is Japan (Bonecco et al., 2017). In recent years, there has been a growing interest in exploring eco-friendly sources of chitosan, like fungi from various industries and insects (Tyliszczak et al., 2020).

MODE OF ACTION

Characteristics of chitosan, such as molecular weight and degree of deacetylation, have a direct influence on physical and chemical properties and biological activity. Furthermore, its efficacy is influenced by factors such as the concentration of application, the type of phytopathogenic organism and the host plant species (Orzali et al., 2017).
How chitosan acts on different microorganisms include:

- Cell membrane/cell wall disruption
- Interactions with the DNA of microorganisms
- Chelation of nutrients necessary for the survival of microorganisms
- Film formation on the surface of microorganisms or plant tissue (Korica, 2020)
- Induction of host plant defense mechanism (El Hadrami et al., 2010).

The presence of amino groups in chitosan is responsible for its biological activity. The inhibition of the growth of microorganisms occurs because the cationic amino groups of chitosan bind to the anionic groups of the cell membrane or cell wall of the microorganism (Janjić, 2010). Interactions between the positively charged molecules of chitosan and the negatively charged components of the cell wall of microorganisms can induce depolarization of the biological membrane and inhibition of the exchange of substances or even the rupture of the cell wall and leakage of the cytoplasm (El Hadrami et al., 2010; Korica, 2020).
Low molecular weight chitosan with a higher degree of acetylation showed a better inhibition of phytopathogenic microorganisms, compared to high molecular chitosans (Román-Doval et al., 2023). Also, low molecular weight chitosans are more soluble in water, pass through cell membranes more easily and can interact with the DNA of the microorganism, thereby affecting protein synthesis and mRNA inhibition.
Chitosan can complex metal ions, making them inaccessible to microorganisms (Korica, 2020). This property comes from the high nitrogen content in chitosan (6.89 %) (Román-Doval et al., 2023).

High molecular weight chitosan forms a dense polymer film on the surface of microorganisms. This process effectively hinders the supply of nutrients and oxygen to the microorganism (Korica, 2020). By forming physical barriers at the points of penetration of pathogens, chitosan prevents the spread of pathogens to healthy tissues (El Hadrami et al., 2010).

Elicitors are compounds that can trigger the plants defense mechanisms. These compounds vary in chemical composition and are recognized by receptors within plant cells, they stimulate local or systemic immune responses (Orzali et al., 2017), which are the result of the production of secondary metabolites of the plant. Low molecular weight chitosan induces the formation, activation and accumulation of defense compounds in plants, lignification, ion flux variations, cytoplasmic acidification, membrane depolarization and protein phosphorylation, activation and accumulation of chitinase, glucanase and phenolic compounds, phytoalexin biosynthesis, generation of reactive oxygen species, jasmonic acid biosynthesis and defense gene expression, and inhibition of host maceration enzymes (Bautista-Baños et al., 2006). It induces the formation of callose and proteinase inhibitors in dicotyledonous species (El Hadrami et al., 2010). The plants defense reactions induced by chitosan are influenced by a variety of factors, such as plant species, pathogen species, and the concentration and characteristics of the applied chitosan (Orzali et al., 2017).

Chitosan stimulates the activity of beneficial microorganisms in the soil, including bacteria such as those from the genus *Bacillus* sp., *Pseudomonas fluorescens*, various actinomycetes, mycorrhizal fungi and rhizobacteria (Bell et al., 1998).

CHITOSAN AGAINST PHYTOPATHOGENIC FUNGI

The efficacy of chitosan in managing economically important phytopathogenic fungi has been thoroughly examined, in laboratory trials and field conditions. Chitosan is applied foliarly, to seed, and as a soil enhancer.

It is a component of the cell wall of certain types of fungi (Bartnicki-Garcia, 1968). One of the first chitosan screening tests was conducted by Allan and Hadwiger (1979), on fungi with different cell wall compositions. The growth of various species characterized by cell walls containing chitosan (class *Zygomycetes*) remained unaffected, whereas chitosan demonstrated inhibitory effects on pathogens belonging to genera *Phytophtora*, *Rhizoctonia*, *Botrytis*, *Fusarium*, *Verticillium*, *Septoria*, *Helminthosporium*.

Chitosans impact is observable in its ability to inhibit mycelial growth, sporulation, and spore germination, which as a result has a reduction of symptoms and disease spreading. It also induces morphological alterations in hyphae and spores. Furthermore, it influences the production of fungal virulence factors (Orzali et al., 2017).

Due to the significant economic losses that *Botrytis cinerea* can cause, numerous researchers have studied the impact of chitosan on this pathogen, across various plant species and under different conditions. The efficacy of chitosan as a fungicide is influenced by the concentration at which it is applied, as well as the targeted

fungal species. Ghaouth et al. (1992) reported that increasing concentration of chitosan led to enhanced inhibitory effects on the mycelial growth of *B. cinerea*, *Alternaria alternata*, *Colletotrichum gloeosporioides*, while *Rhizopus stolonifer* showed the least susceptibility to its effects. Observing *B. cinerea* and *R. stolonifer* on strawberries, Ghaouth et al. (1992) examined the impact of chitosan on spore germination and radial growth of these phytopathogenic fungi, as well as its potential to reduce the strawberry deterioration caused by infection with these pathogens. Chitosan, when applied at concentrations ranging from 0.75 to 6.0 mg/ml, effectively inhibited the spore germination and radial growth of both fungi. Notably, its inhibitory effect was more apparent on *B. cinerea* compared to *R. stolonifer*. Complete inhibition was not attained, suggesting that chitosan displayed fungistatic rather than fungicidal activity. Chitosan disrupts the fungal cell wall, leading to its thinning and inducing the leakage of amino acids and proteins from cells of both *B. cinerea* and *R. stolonifer* within one hour after treatment. In addition, at a concentration higher than 1.5 mg/ml, this biopolymer induced excessive hyphal branching of *R. stolonifer*. Also, Alfaro-Gutiérrez et al. (2014) stated that treating of *R. stolonifer* with chitosan led to various morphological and physiological changes, such as branching, abnormal shape and swelling of hyphae. Cheah et al. (1997) reported similar conclusions about hyphal morphology, when microscopically examining the mycelium of *Sclerotinia sclerotiorum* after treatment with chitosan. They found that it was twisted and branched, compared to the mycelium in the control. Ben-Shalom et al. (2003) stated nearly complete inhibition of conidia germination of *B. cinerea* when applying chitosan at a concentration of 50 ppm under *in vitro* conditions. Furthermore, chitosan suppressed the elongation of germ tube. Microscopic observation of Ait Barka et al. (2004) revealed that chitogel induces morphological and structural alterations in the hyphal cells of *B. cinerea*. *In vitro* experiments demonstrated that chitosan inhibited spore germination, germ tube elongation, and mycelium growth of this pathogen. Additionally, it caused damage to the spore plasma membrane (Liu et al., 2007). This derivative of chitin induces changes in the spore morphology of *C. gloeosporioides* at a concentration of 1.5 %, seven hours after incubation (Bautista-Baños et al., 2003). Also, it influenced aggregation and induced abnormal cell shape, as well as hyphal branching and twisting of *A. alternata* (Reddy et al., 1997). In addition, it led to spore aggregation and morphological changes of the hyphae, which included swelling, polarization and the appearance of germ tubes of *Aspergillus niger* (Plascencia-Jatomea et al., 2003).

Some researchers have examined the effect of chitosan film on the decay of various fruits. Chitosan film applied to strawberries at a concentration of 15 mg/ml had efficacy in reducing strawberry decay, caused by *B. cinerea* and *R. stolonifer*, by over 60 % compared to control (Ghaouth et al., 1992). Du et al. (1997) studied the impact of chitosan film on the preservation of peaches. The application of this biopolymer coating resulted in a reduction in the occurrence and growth of *B. cinerea*. At the end of storage, the decayed area was smaller compared to the control. Chitosan significantly inhibited the growth of *B. cinerea* in Petri dishes.

After 3 days of culture, the colony diameter of this pathogen on KDA medium containing 0, 0.05 and 0.20 % chitosan was 77.4, 65.4 and 25.6 mm, respectively. Cheah et al. (1997) examined the effect of a chitosan film at concentrations of 2 and 4 % on carrot roots. Five days after the treatment, the disease intensity caused by *S. sclerotiorum*, decreased compared to control.

The timing of chitosan treatment can also influence its effectiveness against pathogens. Experiments assessing the efficacy of chitosan applied both pre and post-harvest, revealed that all applied concentrations of chitosan led to a reduction in the occurrence of gray mold of table grapes. Post-harvest treatments comprised immersing grape bunches or berries in chitosan solutions of 0.1, 0.5, and 1 %, followed by inoculation with a pathogen spore suspension. Chitosan solutions at concentrations of 0.5 and 1.0 % exhibited a significantly reduced percentage of infected bunches or berries and a smaller surface area of lesions compared to the control (Romanazzi et al., 2002). Treating with chitosan one hour before inoculation with conidia of pathogen resulted in a 65 % reduction in gray mold occurrence. Treating four or twenty-four hours before spore inoculation reduced disease development by 82 and 87 %, respectively. Treating one hour after inoculation had a slightly weaker effect, reducing the occurrence of the disease by 52 % (Ben-Shalom et al., 2003). Also, de Capdeville et al. (2002) examined the effect of chitosan on *Penicillium expansum*, the causal agent of blue mold, on the apple variety Crveni delišes. Fresh and refrigerated fruits were treated with chitosan, and pathogen inoculation was performed 24, 48 and 96 hours after treatment. Chitosan was found to be effective in controlling the development of the pathogen. However, it was observed that fresh apples exhibited a more favorable response to the treatment compared to those from cold storage. Ait Barka et al. (2004) examined the influence of chitosan in gel form, incorporated into a medium for cultivating vine shoots, on the growth of *B. cinerea*. They confirmed that the increase in concentration of chitogel was associated with an increase in pathogen inhibition. When shoots were inoculated with *B. cinerea*, the characteristic symptoms of gray mold were reduced. The ability of a chitogel-modified medium to inhibit pathogen growth may imply systemic distribution of the chitosan throughout the plant. As stated by Liu et al. (2007), the impact of chitosan on *B. cinerea* and *P. expansum* in tomato fruits may be due to a direct fungicidal effect or induction of the defense mechanism of the host plant. *C. gloeosporioides* shows high sensitivity to the effects of chitosan, as it impacts mycelial growth even at a concentration of 0.5 %. At concentrations of 2.0 and 3.0 %, chitosan completely inhibits the mycelium growth of this fungi (Bautista-Baños et al., 2003).

Hernández-Lauzardo et al. (2008) examined the impact of three chitosans with varying molecular weights on the development of three isolates of *R. stolonifer*. The findings indicated that chitosan with low molecular weight was more effective in inhibiting mycelial growth, whereas high molecular weight chitosan influenced sporulation, spore shape, and germination. Similar results were obtained by Alfaro-Gutiérrez et al. (2014) by treating *R. stolonifer* with oligochitosan, which led to the inhibition of hyphal development. Application of these compounds also resulted in

a significant thickening of the fungus cell wall, increasing it by two to three times. Furthermore, at low concentrations of these compounds, the respiration of *R. stolonifer* is stimulated. The impact of various concentrations of chitosan on the growth and toxin production of *A. alternata*, the causal agent of black spot of tomato, was evaluated by integrating chitosan into the PDA medium at concentrations of 100, 200, 400, 800, 1600, and 3200 µl/ml. After 15 days of incubation, an assessment was conducted. The study concluded that chitosan inhibits the growth and toxin production of this pathogen at higher concentrations. Additionally, it was found that at lower concentrations, the effect of chitosan on toxin production is stronger than on mycelial growth (Reddy et al., 1997). Cheah et al. (1997) studied the impact of three concentrations of chitosan (1, 2, and 4 %) on the mycelial growth of *S. sclerotiorum in vitro*. A chitosan concentration of 4 % demonstrated the highest efficacy in inhibiting mycelial growth. Xu et al. (2007) conducted experiments to evaluate the fungicidal activity of oligochitosan against various phytopathogenic fungi in laboratory tests. They showed that *Phytophtora capsici* exhibited the highest sensitivity among all the tested fungi, which included *B. cinerea*, *Colletotrichum orbiculare*, *Exserohilum turcicum*, *Fusarium graminearum*, *Fusarium oxysporum*, *Verticillium dahliae*. Additionally, they found that oligochitosan had a better inhibitory effect on mycelial growth than chitosan. Plascencia-Jatomea et al. (2003) studied the effect of chitosan and temperature on the germination of *A. niger* spores. Chitosan applied at a concentration of 3 g/l led to the inhibition of the radial growth of mycelia by 73 % after 24 hours, while the percentage of inhibition of spore germination after 13 hours was 40 %. The inhibitory effect of chitosan was stronger at temperatures below 18 ºC. Chitosan reacts with DNA of *A. niger*, affects protein synthesis and leads to mRNA inhibition (Sebti et al., 2005).

Incorporated into the soil, chitosan reduces the occurrence of diseases caused by *Fusarium* sp., *Alternaria solani* and *Aspergillus flavus*. Its effectiveness is presumed to emerge from its ability to stimulate beneficial microorganisms in the soil, such as *Bacillus* sp., *P. fluorescens*, actinomycetes, mycorrhizae and rhizobacteria. These organisms can directly affect phytopathogenic organisms, or they can enhance the plants resistance by improving its defense mechanisms (Orzali et al., 2017). Chitosan has the potential to become an important agent in the control of soilborne pathogens in greenhouse production. Applied at a concentration of 37.5 mg/l in the plant growth medium, chitosan significantly reduced plant death, root rot symptoms and yield losses caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici* on tomatoes grown in a greenhouse. Cytological research revealed that the mechanism of action involves inducing resistance in the host plant against colonization by this pathogen (Lafontaine and Benhamou, 1996). In general, the sporulation of fungi treated with chitosan is reduced compared to the control. Bautista-Baños et al. (2004) examined the inhibition of mycelial growth of three pathogens: *F. oxysporum*, *Penicillium digitatum* and *R. stolonifer in vitro*. Chitosan concentration of 1.5 % effectively suppressed the mycelial growth of *Rhizopus* and *Penicillium* species. Moreover, a

0.5 % chitosan solution notably decreased the sporulation of *F. oxysporum*, while a 1.5 % chitosan solution similarly reduced the sporulation of *R. stolonifer*. However, there are cases when the sporulation is enhanced. *P. digitatum* showed significantly higher sporulation with both concentrations, indicating a stimulating effect probably due to the stressful conditions induced by chitosan. Examination of the biological activity of chitosan on *Pythium aphanidermatum* affecting cucumber plants cultivated in substrates containing either 100 or 400 μg chitosan/ml reaffirmed its efficacy in controlling rot induced by this phytopathogenic fungus. It triggered various defense mechanisms within the host plant, including the development of structural barriers in root tissue and the stimulation of antifungal hydrolases such as chitinases, chitosanases, and β-1,3 chitinases in both roots and leaves. Observation of fungal hyphal cells revealed that chitosan induced cell wall relaxation, vacuolation, and, occasionally, protoplasm disintegration. This may partially elucidate the pathogens limited ability to colonize root tissue in the presence of chitosan. The combined effect of chitosans fungicidal activity and its induction of the defense mechanism make it a promising agent for controlling this pathogen (Ghaouth et al., 1994). Some researchers compared the fungicidal action of chitosan and its derivatives. Rabea and Steurbaut (2010) tested eight chemically modified chitosans on *A. alternata*, *F. oxysporum* and *Pythium debaryanum*. N-(p-fluorobenzyl) chitosan showed the strongest inhibitory activity on the growth of *A. alternata*. The most effective in inhibiting *F. oxysporum* and *P. debaryanum* was N-(o-chloro,o-fluorobenzyl) chitosan. In general, chemically modified chitosans showed a stronger effect on the germination of spores of phytopathogenic fungi compared to unmodified ones.

Seed treatment provides protection and enhances plant development during the initial stages of growth (Orzali et al., 2017). Chitosan increases the content of proline and sugar in seeds, which changes the permeability of the plasma membrane. In addition, it improves enzyme activity (Román-Doval et al., 2023). High molecular weight chitosan possesses biopolymer characteristics and can be applied to seeds forming a film that effectively shields against pathogen infections. In the seed industry, treatment with chitosan consists of immersing the seeds in a chitosan suspension (up to 4 %), followed by drying. Chitosan layers reduce the number of fungi present on the seeds and promote plant growth. The molecular weight of chitosan, the presence of surfactant, the pH value, as well as the thickness of chitosan layers on the seed are parameters that affect seed germination, as well as fungicidal activity and vegetative growth (El Hadrami et al., 2010). Treating wheat seeds with chitosan, for protection against *F. graminearum*, led to an increase in yield by 20 %, alongside enhancements in seed quality and germination potential (Reddy et al., 1999). Attjioui et al. (2021) showed strong synergistic effects of chitosan polymer and oligomers in inhibiting conidia germination and fungal growth of *F. graminearum*. Chitosan is also used as a protective coating on corn seeds to protect against *Fusarium moniliforme* and *A. flavus* (Román-Doval et al., 2023).

Mazaro et al. (2009) treated tomato and sugar beet seeds by immersing them in a chitosan suspension. The seeds were subsequently planted in containers containing substrate infected with *Rhizoctonia* sp. and placed in a greenhouse for 14 days. Chitosan enhanced seed resistance against this pathogen, elevating the activity of phenylalanine ammonia-lyase while affecting the total protein content and total and reducing sugars in the leaves.

Chitosan has also found application as a carrier for various active substances, such as essential oils, protecting them from various environmental factors and thus extending their persistence. By applying a film of chitosan and essential oil to wheat seeds, the development of *F. graminearum* was reduced compared to the control, without a negative effect on germination and plant development in the initial stages. In addition, chitosan film on corn and wheat seeds increased seed germination rate and stress tolerance. Chitosan diffuses through seed integuments, affects cell metabolism and thus induces a series of plant defense reactions (Orzali et al., 2017).

SYNERGISTIC EFFECT OF CHITOSAN AND FUNGICIDES

In recent years, a lot of research has been conducted on the synergistic effect of chitosan and conventional fungicides. This approach holds promise for reducing chemical pesticide usage while effectively controlling pathogens. Chito-oligosaccharides enhance the effectiveness of synthetic fungicides. This was observed with *B. cinerea* on strawberries and *Venturia inaequalis* on apples, under both *in vitro* and *in vivo* conditions. The researchers studied both the separate and combined effects of chito-oligosaccharides and synthetic fungicides, which included active ingredients such as fenhexamide, cyprodinil and fludioxonil, azoxystrobin, boscalid and pyraclostrobin, and dithianon. The most significant synergistic effect was observed on *B. cinerea*. When applied individually at a lower concentration, a fungicide containing boscalid and pyraclostrobin, as well as chito-oligosaccharide, did not significantly inhibit spore germination. However, when combined, they reduced spore germination by 90 %. Previous research suggests that chito-oligosaccharide increases the membrane permeability of fungi, which allows fungicides to reach their site of action more quickly (Rahman et al., 2014). Le et al. (2019) found that a mixture of silver-incorporated chitosan nanocomposites and fungicide propineb exhibit notably enhanced antifungal efficacy against *P. capsici* compared to each component. Lemke et al. (2022) showed that a mixture of low molecular weight chitosan and copper acetate act synergistically and enable a 50 % reduction in copper concentration while still retaining the antifungal effectiveness against *F. graminearum*. Chitosan combined with copper fungicides, is more effective against *Plasmopara viticola* than copper alone (Romanazzi et al., 2024). These authors conducted a three-year-long experiment in three vineyards under different environmental conditions. They applied 0.5 % chitosan alone, in rotation with copper and combination with copper, and also conventional fungicides without chitosan. The control stayed untreated. Chitosan treatments consistently decreased the grapevine downy mildew

McKinney Index on both leaves and bunches. When applied alone, chitosan exhibited lower efficacy compared to copper. However, after copper it had similar effectiveness. In combination with copper, it had greater efficacy than the copper standard. Ippólito et al. (2017) found that the combination of low, ineffective doses of mancozeb with chitosan successfully suppresses *Phytophtora infestans* in potatoes. It is presumed that such efficacy is a result of the fungicidal activity of chitosan and its ability to induce the plants defense mechanisms.

CONCLUSION

Based on numerous studies, it can be concluded that chitosan has good activity against many plant pathogens. This polymer has been established as a notable inducer of plant resistance. Hence, biopesticides based on chitosan hold the potential to supplement conventional pesticides in integral and conventional plant protection. This can be the effective management of control of pathogens to minimize the negative impacts of chemical pesticides. However, the effectiveness of chitosan-based biopesticides depends on numerous factors, such as the species of phytopathogenic organism, chemical characteristics of chitosan, application method and concentration, and environmental conditions. Indeed, we can expect that this natural substance will occupy a significant place in the future for controlling harmful agents in agricultural production.

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SURVEY ON THE PRESENCE OF QUARANTINE BACTERIA OF GRAPEVINE *XYLOPHILUS AMPELINUS* IN REPUBLIC OF SRPSKA 2019-2022

Vojislav TRKULJA*, Gordana BABIĆ, Bojana ĆURKOVIĆ, Bojana VUKOVIĆ, Jovana PRIJIĆ, Bogdan NEDIĆ

PI Agricultural Institute of Republic of Srspka, Banja Luka, Bosnia and Herzegovina
*Corresponding author: vtrkulja@blic.net

ABSTRACT

Xylophilus ampelinus, the causal agent of bacterial necrosis in grapevine is listed in Annex II, Part A, Section II of the Directive 2000/29/EC. The only known host of these quarantine bacteria is grapevine. Considering that *X. ampelinus* is listed on quarantine I A1list in Bosnia and Herzegovina, and due the high direct and indirect impacts in yield reduction, death of host plants and specific disease management procedures survey in Republic of Srpska (RS) was approved and financed by the Ministry of Agriculture, Forestry and Water Management of RS since 2019. Sampling of host plants was carried out in seven regional units of RS in registered nurseries and seedling production places, farms, as well as at border crossings in RS. Laboratory analyses were carried out in accordance with the EPPO diagnostic protocols: PM Bulletin 39, 403–412. Protocols include extraction from symptomatic and asymptomatic plant material, followed by isolation or two tests based on a different principle: DAS-ELISA for the serological and a conventional PCR test for the molecular detection. Manceau*et al*. (2005) protocol was used for DNA extraction and a set of primers Xa TS1 5`-TGC GTA GTT CAA CAC CAA AGT-3`, Xa TS2 5`-TAT GAC CCT CTT TCC ACC AGC-3` or Xa TS2 BIO 5`Biotine-TAT GAC CCT CTT TCC ACC AGC-3` was used for the detection of *X. ampelinus*. During 2019, 2020, 2021 and 2022, 65, 58, 40 and 30 samples were analyzed, respectively. All tested samples were *X. ampelinus* negative, but considering consequences if bacteria occur, surveillance program is continued in 2023.

Keywords: *Xylophilus ampelinus, grapevine, survey, Republic of Srpska.*

INTRODUCTION

Xylophilus ampelinus (Panagopoulos) Willems *et al*. is the plant pathogenic bacterium causing 'bacterial blight' of grapevine. The disease was originally described in Greece (Crete) and was named *Xanthomonas ampelina* (Panagopoulos, 1969). It was transferred to the new genus *Xylophilus* (Willems *et al.*, 1987) on the basis of DNA and RNA studies.

The bacterium infects only grapevine (*Vitis vinifera* and *Vitis* spp. used as rootstock). It is recorded in Mediterranean country, (Italy) by Garovaglio and Cattaneo (1879), Baccarini (1893) and Macchiati (1897), from the end of the 19th century. However, recent years is present sporadically in Sicily and Sardinia, but also in other EU countries (northern France) (EFSA, 2014). Sampayo *et al*. (1981), Lopez, (1983), Gomez and Lopez (1986), Gracia *et al*. (1988) and Cambra Álvarez (1997) recorded bacteria in Spain. Panagopoulos and Psallidas (1983) and Panagopoulos (1987) recorded *X. ampelinus* in Greece, while Dreo *et al*. (2005a, b) confirmed present of bacteria in Slovenia, even it is observed since the late 1950s in western Slovenia (Seljak *et al*., 2005). Apart from the mentioned countries, according to EPPO (2023) *X. ampelinus* was detected also in 1994 in Moldova, Japan (2009 in Hokkaido and 2014 in Honshu), 2016 in Jordan, 2020 in Russia and 2022 in Ukraine. Concidering that the pest has a limited distribution in the EU it is listed in Annex II, Part A, Section II of the Directive 2000/29/EC. The only known host of this quarantine bacteria is grapevine (EPPO, 2009). Considering that *X. ampelinus* is in Bosnia and Herzegovina (B&H) listed on quarantine I A1 list (Trkulja *et al.*, 2012), and due the high direct and indirect impacts in yield reduction, death of host plants, their distribution in Republic of Srpska (RS) and specific disease management procedures the survey in RS was approved and financed by Ministry of Agriculture, Forestry and Water Management of Republic of Srpska from 2019.

MATERIALS AND METHODS

Survey on the presence of quarantine bacteria of grapevine *Xylophilus ampelinus* in RS was approved and financed by Ministry of Agriculture, Forestry and Water Management of RS during 2019-2022. Sampling of host plants was carried out in seven regional units of RS (Prijedor, Banja Luka, Gradiška, Doboj Bijeljina, Istočno Sarajevo and Trebinje) in registered nurseries and seedling production places, production farms and agricultural households, as well as on border crossing during their import. From Table 1, it can be seen the number of samples and places where host plant samples were taken for laboratory analysis of the presence of quarantine bacteria *X. ampelinus* in the territory of the Republic of Srpska in the period 2019-2022.

Table 1. Sample number and locations where host plant samples were taken for laboratory analysis of the presence of bacteria *X. ampelinus* in the period 2019-2022

Locations where host plant samples were taken for laboratory analysis	**Sample number for laboratory analysis per year**			
	2019	**2020**	**2021**	**2022**
Registered nurseries and producers of seedlings of agricultural plants	5	0	0	0
Production farms and agricultural households	55	55	37	28
Host plants from import	5	3	3	2
Total:	65	58	40	30

According to the "Special surveillance program for the presence of quarantine pest *X. ampelinus* (Panagopoulos) Willems *et al.* – bacterial necrosis in grapevine in Republic of Srpska" (Official Gazette of the Republic of Srpska 56/19, 34/20, 41/21 and 33/22) every inspection and sampling were mapped, recorded and digitized using FITO GIS software (Photo 1-4).

Laboratory analysis were carried out in accordance with the EPPO diagnostic protocols: PM Bulletin 39, 403–412. Protocols include extraction from symptomatic and asymptomatic plant material, folowed by isolation or two tests based on a different principle: DAS-ELISA for the serological and a conventional PCR test for the molecular detection. Manceau *et al.* (2005) protocol was used for DNA extraction and set of primers Xa TS1 5`-TGC GTA GTT CAA CAC CAA AGT-3`, Xa TS2 5`-TAT GAC CCT CTT TCC ACC AGC-3` or Xa TS2 BIO 5`Biotine-TAT GAC CCT CTT TCC ACC AGC-3` was used for the detection of *X. ampelinus.*

RESULTS AND DISCUSSION

Regarding Commission for plant health protection proposal at Ministry of Agriculture, Forestry and Water Management of RS, survey on the presence of quarantine bacteria of grapevine *X. ampelinus* started in 2019. Program survey was publish in Official Gazette of RS 56/19. Sampling of host plants was carried out in a registered nurseries and seedling production places, production farms and agricultural households in six regional units of RS (Prijedor, Banja Luka, Doboj, Bijeljina, Istočno Sarajevo and Trebinje), as well on crossings border in RS. During 2019, total 65 samples were analyzed in Laboratory for plant protection, seed and biotechnology in PI Agricultural Institute of Republic of Srspka, Banja Luka. 55 samples were analyzed from production farms and agricultural households, while 5 samples were analyzed from nurseries and seedling production placess, as well 5 samples from crossings border. Also according Official Gazette of RS in case of suspected samples, sampling of larger number from nurseries, seedling production placess and crossings border was predicted for laboratory analysis. All tested samples were negative for the presence of the quarantine bacterium *X. ampelinus.*

During 2020, Ministry of Agriculture, Forestry and Water Management of RS publish "Program survey on the presence of quarantine bacteria of grapevine *X. ampelinus* in RS" in Official Gazette of RS 34/20. Sampling of host plants was carried out in a production farms and agricultural households in six regional units of RS (Prijedor, Banja Luka, Doboj Bijeljina, Istočno Sarajevo and Trebinje), as well on crossings border in RS. During 2020, total 58 samples were analyzed in Laboratory for plant protection, seed and biotechnology, PI AIRS, BL. 55 samples were sampled and analyzed from production farms and agricultural households, while 3 samples were analyzed from crossings border. As previous year, according Official Gazette of RS in case of suspected samples, sampling of larger number from nurseries, seedling production placess and crossings border was predicted for laboratory analysis. The presence of the quarantine bacterium *X. ampelinus* was not

detected in any of the tested samples. The geographic distribution of the host plant samples taken in the territory of the Republic of Srpska during 2019 and 2020 are shown in Photo 1 and 2.

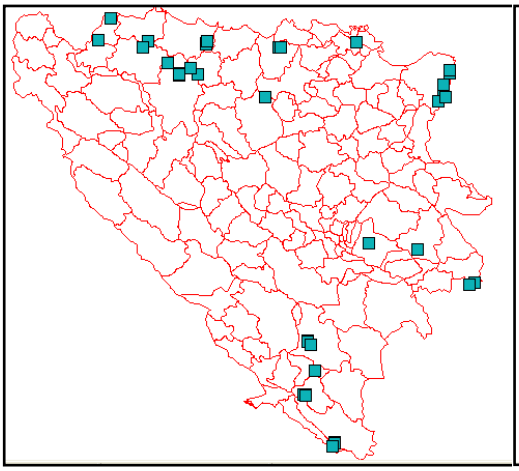

Photo 1. Fito GIS mapping – X. ampelinus, visual inspection and sampling in Republic of Srpska,2019

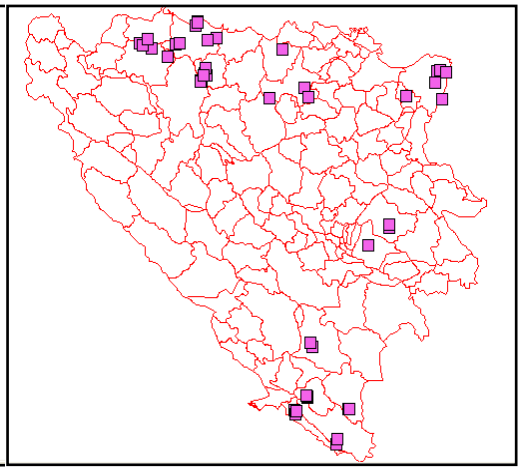

Photo 2. Fito GIS mapping – X. ampelinus, visual inspection and sampling in Republic of Srpska,2020

In 2021, „Program survey on the presence of quarantine bacteria of grapevine *X. ampelinus* in RS" was published in Official Gazette of RS 41/21. Sampling of host plants was carried out out in a production farms and agricultural households in seven regional units of RS (Prijedor, Banja Luka, Gradiška, Doboj Bijeljina, Istočno Sarajevo and Trebinje), as well on crossings border in RS. During 2021, total 40 samples were analyzed in Laboratory for plant protection, seed and biotechnology, PI AIRS, BL. 37 samples were sampled and analyzed from production farms and agricultural households, while 3 samples were analyzed from crossings border. According Official Gazette of RS in case of suspected samples, sampling of larger number from nurseries, seedling production placess and crossings border was predicted for laboratory analysis. All laboratory tested samples were negative for the presence of bacteria *X. ampelinus*.

During 2022, „Program survey on the presence of quarantine bacteria of grapevine *X. ampelinus* in RS" was published in Official Gazette of RS 33/22. Sampling of host plants was carried out in a registered nurseries and seedling production places and farms in seven regional units of RS (Prijedor, Banja Luka, Gradiška, Doboj Bijeljina, Istočno Sarajevo and Trebinje), as well on crossings border in RS. During 2022, total 30 samples from production farms and agricultural households were analyzed in Laboratory for plant protection, seed and biotechnology, PI AIRS, BL, while samples from nurseries, seedling production placess and crossings border were planed according Official Gazette of RS in case of suspected

samples. All tested samples were negative for the presence of the quarantine bacterium *X. ampelinus.* The geographic distribution of the host plant samples taken in the territory of the Republic of Srpska during 2021 and 2022 are shown in Photo 3 and 4.

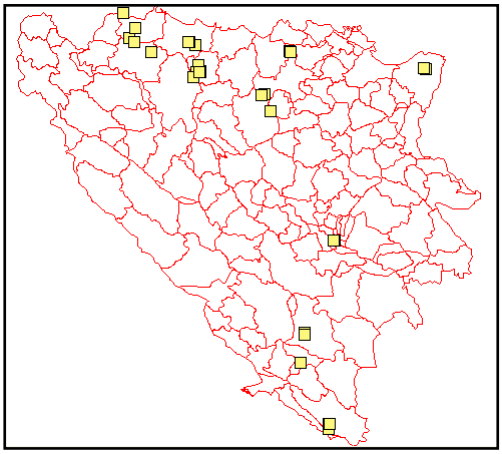

Photo 3. Fito GIS mapping – X. ampelinus, visual inspection and sampling in Republic of Srpska,2021

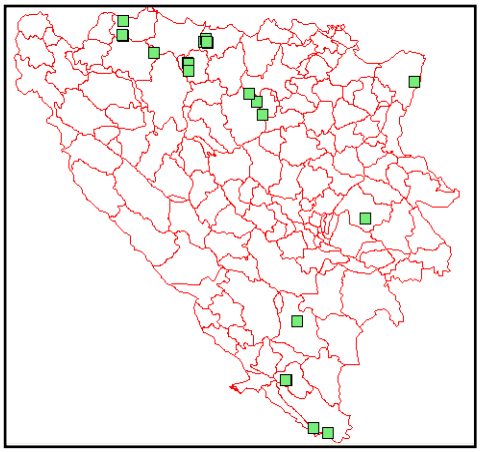

Photo 4. Fito GIS mapping – X. ampelinus, visual inspection and sampling in Republic of Srpska,2022

CONCLUSION

Based on the conducted laboratory analysis during 2019-2022, all tested samples were negative for the presence of quarantine bacteria of grapevine *X. ampelinus*, whose surveys was carried out under the Program approved and financed by Ministry of Agriculture, Forestry and Water Management of RS. Considering consequences if bacteria occurs, program survey is also continued in 2023, in order to ascertain and monitor the presence status of this quarantine pathogen in the RS, so in case of its occurrence, that emergency measures can be implemented and further spreading could be prevented.

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RELATIONSHIP BETWEEN CERTAIN ANIMAL WELFAR PARAMETERS AND THE PHYSICO-CHEMICAL AND MICROBIOLOGICAL QUALITY OF MILK

Nassima BOUHROUM*, EL Hassen LANKRI

Laboratory of Bioresources Natural Local, Department of Agronomy, Faculty of Nature and Life Sciences, University of Hassiba Ben Bouali Chlef, Ouled Fares, Algeria
*Corresponding author: n.bouhroum@univ-chlef.dz

ABSTRACT

In Algeria, dairy farms face a major problem related to poor management of animal welfare, which leads to a decline in milk production in terms of quality and quantity. The objective of this study was to verify whether there is a link between animal welfare parameters and milk quality. The experiment was carried out at two dairy farms in the wilaya of Chlef on a staff of 30 dairy cows of Prim Holstein and Montbéliard breed. These females were followed after calving by sampling milk and evaluating mastication index, rumen filling, dung consistency and udder cleanliness at day 7 and day 14. Milk samples were transported in a cooler for physicochemical analysis by measuring fat, total dry extract, degreased dry matter, pH, titratable acidity, density, conductivity and acidity of fat. The isolation of coliforms was carried out to verify the hygienic quality of milk. The results showed that with a cleanliness score equal to (2,33 ; 2,4) during the cold and hot season respectively the hygienic quality of the milk was unsatisfactory with a conductivity of (7,75 ; 7,40) and number of coliform was (8,01- 8,86) $\times 10^3$ UFC respectively with a $p>0,05$. The observed fluctuation in fat, total dry extract and degreased dry matter during the first and second week of the parturition at the rate of [(33,04; 24,14); (125; 120); (88,43; 85,76)] g/l with $p<0,05$ respectively was caused by subclinical mastitis thus excluding the dietary cause. Because the index of mastication, the filling of the rumen and the consistency of dung were in the range of the usual values at the rate of (52,82) m/min; (3); (3,4) respectively as well as the acidity of the fat at the rate of (0,48; 0,55) respectively with a $p>0,05$. In conclusion, the origin of subclinical mastitis was the poor hygienic condition of the udder, which led to contamination of the milk by coliform bacteria, resulting in a decrease in the physicochemical quality of the milk.

Key words*: conductivity, milk quality, season, subclinical mastitis.*

INTRODUCTION

Production diseases in high-producing dairy cows occur primarily in early lactation. This diversion in metabolism promotes the development of associated

pathologies (metritis, mastitis, fertility disorders, etc.) thus decreasing the performance of animals. So the economic impact of these diseases is not negligible especially to achieve the goal of one calf per cow per year. Calving is considered a state of stress (ill-being) for the dairy cow and is related to an energy balance that is at its lowest level the week following the share, thus, biologically speaking this situation will generate a response from this organism to be able to live in better conditions. (Bouhroum et al., 2013). Stress reactions consume energy and weaken the body on several levels, threatening animal welfare and production and reproduction. (Bouhroum et al., 2014) To increase milk production in Algeria it is necessary to ensure well-being around calving by playing on the comfort level of the calving area, the psychological, physiological, behavioral and health level. (Bouhroum et al., 2022) We noticed in the field that the breeder is a main stressor, because he does not control well the management of animal welfare, for him the animal is used for his product and for his work force. The animal is considered in this materialistic conception as a being without sensitivity, which can therefore be subjected to any constraint without suffering. (Fraser, 2011) The objective of the study is to assess the welfare of dairy cows using peripheral indicators and in parallel to analyze the hygienic and physicochemical quality of milk to deduce the relationship between them.

MATERIAL AND METHODS

Our study was carried out during the month of July 2023 until May 2024, at the level of two dairy farms in the wilaya of Chlef on a staff of 30 cows of Prim Holstein and Montbéliard breed. These cows were followed at day 7 and day 14 after calving in order to collecte milk for physicochemical and microbiological analysis and to determine certain animal welfare parameters such as:

- Mastication index based on the method of (Denwood et al., 2018).
- Dung consistency based on the method (Guedon., 2017).
- Rumen filling using the method of (Burfeind et al., 2010).
- Udder cleanliness scoring was done using a scoring grid from Lensink et al., in (2012), cows with score 1 are considered “very clean” while cows with score 5 are considered “very dirty”.

The pH of the milk was measured at 20°C with a pH meter type (HANNA Instruments), The acidity was measured by titrating with a NaOH solution. Ten ml of raw milk was taken and poured into a beaker to add three to four drops of phenolphthalein and the mixture was homogenized. The 0.1N NaOH solution was added by drip until the color turn to pink at room temperature to titrate. Density was determined at 35 to 20°C using a thermo lactodensimeter using the Maiworé et al., method in (2018). Fat was determined using an acido-butyrometric method called GERBER. (Koceir, 2010). The total dry extract content is the product of evaporation in a water bath at 70°C and drying of the sample (10 ml) in the oven for 3 hours at 105 ± 2°C. The degreased dry extract was obtained by the following formula : ESD (g/l) = EST-MG (EST = total dry extract; MG = fat). The electrical

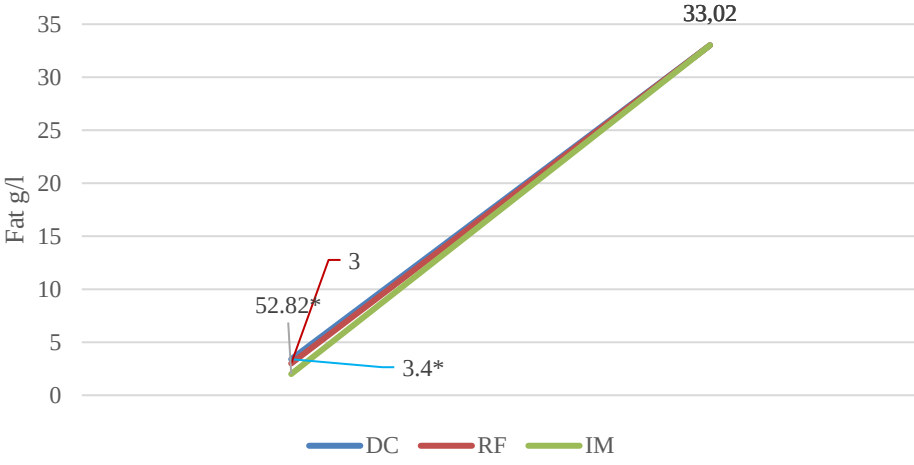
conductivity of the sampled milk was measured using a conductivity meter (EC 215, Hanna Instruments). Free acidity of fat was determined using the BDI method of (Evers, 2003). Isolation of coliforms was performed on desoxycholate agar. Statistical analysis was performed by the SPSS software using the student test.

RESULTS AND DISCUSSION

Milk fat

At the level of Table 1, the milk fat is high during the first week of post partum at a value of 33.04 g/l compared to the value of the second week of post partum at a value of 25.14 g/l with a $p<0.05$. By comparing our results with other studies on the same parameter using the same Gerber method. We can say that our results are lower than the result found by (Hamidi et al., 2020) who obtained a rate of (41 g/l), and that of (Zoghlami et al 2022). Our fat results in the first week range from 25.14 g/l (Tir et al., 2015) to 37g/l (Siboukeur et al., 2012). While those of the second week are very low compared to a good quality milk that must have a rate of 35g/ l of fat with a minimum tolerated limit of 27g/ L (Amroun and Hadjab, 2021). This difference in the results is probably related to the forage content and the nature of the fibres of the concentrates used in the dairy rations. A diet rich in cellulose that produces acetic acid promotes an increase in milk fat (Cauty and Perreau, 2009). But according to the acidity of the fat during the first week and the second week of the post partum which is equal to (0.486, 0.553) respectively with a $p>0.05$. It was noted that there is a de novo synthesis of carbon-number fatty acid between (10-12) according to (Deeth et al., 1975) at the level of the udder which means that the cause of the fall in fat is not food, because milk fatty acids come from two very distinct sources (food and from the mobilization of fat reserves) and the length of the carbon chain indicates their origin.

Figure 1:Fat according to dung consistency, rumen filling and mastication index



The mammary gland produces fatty acids with a carbon chain limited to 14 carbon atoms and this synthesis mainly uses acetate and butyrate as substrate. These two dietary compound will be extracted from the bloodstream and lengthened by sequential addition of two carbon atoms to form a variety of short and medium chain fatty acids (Enjalbert, 2016). This means that the origin of this decrease is not food and this is also confirmed by the parameters of animal welfare (IM, CB, RR) which is found in the standards at values of (52.82; 3.4; 3) respectively for a fat of 33.02 g/l. (Figure 1) Other factors can significantly influence milk fat such as lactation stage (Legarto et al., 2014), Total milk production follows an inverse evolution of milk fat concentration (Kaouche-Adjlane, 2019). Indeed our results showed a fall in fat around the third week of the post parum.

Total dry extract

We observe at the level of Table 1 that the total dry extract is higher during the 1st week of the post partum compared to the 2nd week at a value (124.93; 120.36) g/l respectively with a $p<0.05$ and it is found in the range of the usual value. This value is between (87.49 and 128) g/l indicated by (Tir et al., 2015; Siboukeur et al., 2012) respectively. This content means that the milk studied has not been diluted (Tir et al., 2015) effectively the density found in the milk sampled confirms this.

Degreased dry matter

Table 1 shows that the degreased dry matter is identical during the first week and the second week of the post partum at a value (8.43; 85.76) g/l respectively, but without reaching the usual value. According to Souleymane et al. (2013), low-energy rations reduce the rate of degreased extract.

Table 1. Physicochemical parameters of milk during the first and second week of the parturition

	d7	d14	usual value	*p Value*
fat g/l	M= 33,04*	M= 25,14	37 (Siboukeur et al 2012)	0,003
the total dry extract g/l	M= 125*	M= 120	87,49 (Tir et al 2015) 128 (Siboukeur et al 2012)	0,031
the degreased dry matter g/l	M= 88,43	M= 85,76	94,47 (Debouz et al 2014)	0,12
pH	M=6,55*	M= 6,61	6,74 (Titaouine 2018)	0,03
titratable acidity	M= 16,55	M=16,79	16,8 (Titaouine 2018) 15-18 (Leymarios 2010)	0,18
density	M= 1,03	M=1,04*	1,03 (Titaouine 2018)	0,001
Free acidity of fat	M=0,48	M=0,55	0,42 (Acide Caprique : C10) 0,71 (acide Laurique : C12) (Deeth et al., 1975)	0,28

**=p<005, M= Mean*

pH

It is observed at the level of Table 1 that the pH is lower during the 1st week of the postpartum compared to the 2nd week at a value (6.55; 6.61) respectively with a $p<0.05$ and it is a value which is below the interval of the usual value. The pH determines whether the milk is fresh or fermented. (Koussou et al., 2007)

According to Ouadghiri (2009), there is a natural presence of lactic acid bacteria in the udders of cows, which may explain the pH drop during the first week of the parturition.

Titratable acidity

Table 1 shows that the titratable acidity is identical for the two weeks of the parturition at a value (16.55; 16.79) respectively with a $p>0.05$. The results obtained on acidity revealed values equal to the norm. This means that the refrigeration system at the farm level was correct because when the milk is not cooled immediately and the ambient temperature is high, it can acidify. (Debouz et al., 2014)

Density

We observe at the level of Table 1 that the density is higher during the 2nd week of the parturition compared to the first week at a value (1.04; 1.03) respectively with a $p<0.05$ and this is a value that lies within the range of the usual value. This can be explained by the fact that farmers did not use fraudulent milk wetting to increase their income. (Kouame-Sina et al 2010) and it can also be explained by the fall in fat (Debouz et al., 2014)

Electrical conductivity, coliform number, season and degree of cleanliness of the udder

Table 2 *presents the results* that the electrical conductivity of milk has a value of (7.75; 7.40) ms/cm during the cold and hot season respectively with a degree of cleanliness of the udder equal to (2.33; 2.4) respectively with a $p>0.05$.

Table 2. The conductivity of milk, the number of coliform and cleanliness of the udder during the cold and hot season

parameter / season	C E du lait (mS/cm)	Coliforme (UFC)	Propreté Mamelle
cold	M=7,75	$8,01\times10^3$	2,33
hot	M=7,40	$8,86\times10^3$	2.4
p value	p=0,58	p=0,48	p=0,50
Critical interval	CE > 7 mS/m (subclinical mastitis) (Mir et al 2018)	(5×10^2- 5×10^3) ufc/g (JORA 2017)	(0-1) (Lensink et al 2012)

*=*p<005, M= Mean, CE=* electrical conductivity

Values that exceed the critical interval. This means that the udder has subclinical mastitis because the value of 11.20 mS/cm is considered a threshold for severe clinical mastitis. (Mir et al., 2018) It was also noted that the number of Coliform is identical during the cold and hot season at a rate of (8.01-8.86) respectively with $p>0.05$ by exceeding the microbiological limit (JORA, 2017). It can be said that there is no seasonal effect on the appearance of mastitis but there is a hygienic effect, According to Darej (2019), says that The production of quality milk does not require expensive facilities on the farm, neither ruinous transformations in the commercial and industrial system. It is essential that good hygiene practices are followed rigorously and continuously throughout the production process, especially when milking. According to Bouhroum et al. (2022) there is significant negligence in hygienic practices during milking.

CONCLUSIONS

The present study revealed that the hygienic quality of raw milk is unsatisfactory and that the milk are highly contaminated, revealing suspicious hygiene practices that even the best refrigeration conditions cannot hide. The results of the physico-chemical analyses are generally included in intervals close to the international standards for milk alone, fat, total dry extract and degreased dry matter are on average, low compared to the standard, and this fall is related to the environmental sub-clinical mastitis caused by coliform. These results confirm the importance of technical support for sustainability and the exhortation of the dairy sector in Algeria.

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SOCIO-ECONOMIC FACTORS INFLUENCING SUSTAINABILITY OF THE HOMESTEAD FOOD GARDENS: A CASE OF HOUSEHOLDS IN GAUTENG PROVINCE, SOUTH AFRICA

Maritz MAHLANGU[1], Phokele MAPONYA[2]*, Simon LETSOALO[3]

[1]Gauteng Department of Agriculture and Rural Development, South Africa
[2]Agricultural Research Council - Vegetable, Industrial and Medicinal Plants, South Africa
[3]North West University, Faculty of Natural and Agricultural Sciences, South Africa
*Corresponding author: maponyap@arc.agric.za

ABSTRACT

Homestead Food Gardens (HFG) are considered a means through which households can improve their living through food production. Too many resources are directed to the HFG program to help eradicate poverty and food insecurity. The study aims to create sustainable management for homestead food gardens in the Germiston and Randfontein regions of Gauteng Province, South Africa. The following objectives were followed: to identify socio-economic factors that encourage homestead food gardens in Germiston and Randfontein regions, to assess production practices of the homestead food gardens in the Germiston and Randfontein regions and to recommend an improved sustainable mechanism for the homestead food gardens in the Germiston and Randfontein regions. A total of 880 households participated in the study. Both qualitative and quantitative study methods were applied and the English language was used during writing in the questionnaire, and discussions with stakeholders and observations were also part of the data collection. Purposive sampling was used to select 880 households from the list provided by the Gauteng Department of Agriculture and Rural Development (GDARD). The data were captured, analyzed and coded through the use of Statistical Package for Social Science (SPSS version 21). Out of the 880 households that participated in the study, 340 indicated that this practice was good, 445 good, 54 fair, 19 poor and 22 very poor. In terms of homestead food gardens sustainability: 147 were able to generate income, 179 were only aware of environmental matters and 527 were supporting social initiatives. Correlation results also indicated a positive association among the following variables: availability of garden, household members, age and household income. The study recommended the following activities to be improved in the program: Communities and stakeholder mobilisation, situation analysis, food gardens inputs, demonstration, training and technical assistance, educational nutrition, monitoring and evaluation and crop based approach.

Keywords: *Food Security, Homestead food garden, Germiston and Randfontein Regions, Gauteng Province, South Africa.*

INTRODUCTION

According to Galhena (2013), Homestead Food Garden (HFG) is amongst the most ancient practices of food production that is practiced throughout the world. It differs often in biodiversity, size and products are adapted to local resources and the preference of culture. HFG are referred sometimes to as backyard, mixed, roof top garden, farmyard, kitchen and homestead gardens or compound and can also be categorized into the following two groups: "promoted gardens" – they receive support and intervention from outside organization and "traditional gardens" – those which are cultivated independently without any intervention.

The homestead food garden advantage in terms of its benefits to the economy includes growing your own vegetables and fruits becoming less expensive than purchasing products from the markets. According to FAO (2012), a surplus can be sold in addition, providing household with livelihood additional source of income and opportunities. Generally, surplus income can be used for the purchase of supplement food items, it further increases the diversification of the diet of the family thus overcoming seasonal foods availability and ensuring self-sufficiency promotions in the households. According to Stemele (2014) and Maponya (2019), South Africa is a nation seen to be 'food-secure', enough calories are produced to feed 53 million of its people adequately. However, since 1994 during the birth of democracy, some progress has been realised, in four people every one of them currently on a regular basis suffers hunger and a population of more than half finds themselves living in similar circumstances which are precarious risk of going hungry. At the country and national level, South Africa exceeds the benchmarks of most global for amounts of food exported and produced. However, the same cannot be said at the household level (Stats SA, 2017).

Gauteng Province population is over 12 272 263 million individuals contributing 23.7% of the population at the total national level (StatsSA, 2018). According to different Gauteng Province household's studies, almost 20% go to sleep without having food due to income unsustainability and food insecurity (Maponya, 2019). In addition, different studies indicated food gardening as a means to supplement household income, and for addressing food security as it addresses more precisely nutrition (Maponya, 2019). Different food security programs were initiated by the Gauteng Province in the current situations and past e.g. Siyazondla, HFG; growing own campaigns of food which are to be recognized and accepted since improvements were significantly made in the rural provincial residents and their livelihoods. Various interventions in the province have been done to address the food security issue through the consideration of food gardening and the challenge facing Gauteng Department of Agriculture and Rural Development (GDARD) is to ensure that the programs remain sustainable and active even after the government ceases its support.

According to Kongolo & Bamgose (2002) characteristics of the socio-economic effect are amongst forces that discourage or encourage change towards agriculture behavior in the rural people. A revelation in recent studies showed a great linkage

of individual importance, socio-economic level and its participation and involvement in the development of agriculture.

Socio-economic factors impact men intricacy, farming is a function performed by human and subsequently their benefits and achievements from agriculture. Meenar & Hoover (2011) after the assessment of 52 issues of hunger, food insecurity in the community and the garden results in the neighborhoods of Philadelphia emphasized factors in the socioeconomics may determine most importantly participation in household gardens.

The research aim is to create sustainable management for homestead food gardens in the Germiston and Randfontein regions of Gauteng Province, South Africa. The following objectives were followed: To bring out socio-economic factors that encourage homestead food garden sustenance in Germiston and Randfontein regions, to assess production practices of owners of the homestead gardens in the Germiston and Randfontein regions and to recommend an improved mechanism sustainable for the homestead gardens in the Germiston and Randfontein regions.

MATERIAL AND METHODS

Study Area

The research focused on the Randfontein and Germiston Regions. In the Randfontein region, the following municipalities were included: City of Johannesburg Metropolitan Municipality, Mogale City, Randfontein, Merafong City and Westonaria. In the Germiston region, the following municipalities were included: Ekurhuleni Metropolitan Municipality, Lesedi, Midvaal and Emfuleni.

Study Design

The research employed both qualitative and quantitative methods concurrently and this was applied with the aim of making sure that one type of limitations of the data is extremely balanced through the strengths of the other. Integrating different ways of knowledge ensured improved understanding. HFG beneficiaries were interviewed in such a way to assess the type of vegetables that the beneficiaries of homestead food gardens prefer to grow, the type of soil, if the soil is suitable for the preferred planted crops. Data collection methods were via interviews, site observations, focus groups, past researches, web and governmental reports. A detailed questionnaire was developed for the collection of data in English. Pre- and post-intervention questionnaires were developed and pilot-tested with researchers working on community development within the Agricultural Research Council (ARC) organization. Homestead food gardens beneficiaries were interviewed. The questionnaire focused on obtaining socio-economic characteristics, as well as the frequency of eating vegetables, food security and field observation checklist for cultivation practices. Additional open-ended questions were also included to identify key challenging areas, which are likely to affect the sustainability of homestead food gardens. The focus group discussions also were undertaken among 32 officials in the GDARD as follows: Combined West Rand and City of Johannesburg (18), Sedibeng (7) and Ekurhuleni (7).

Sampling Procedure and Analytical Technique

A purposive sampling technique was used on selected 880 households from the Districts and Metropolitans within the Randfontein and Germiston Regions. The list of 8800 households were supplied by the GDARD and all received starter packs. The research sample size was agreed with the stakeholders. A rule of thumb was applied, which is the minimum selection of 10% of the population and it is considered as a good sample size.

Data collected was analysed quantitatively using the Statistical Package for Social Sciences (SPSS) Windows version 25. Descriptive and correlation analyses were done. Correlation is a bivariate analysis that measures the strengths of the association between two variables and the direction of the relationship. In terms of the strength of the relationship, the value of the correlation coefficient varies between +1 and -1. When the value of the correlation coefficient is around ± 1, then it is said to be a perfect degree of association between the two variables. As the correlation coefficient value moves towards 0, the relationship between the two variables will be weaker. The direction of the relationship is simply the + (indicating a positive relationship between the variables) or - (indicating a negative relationship between the variables) signs of the correlation. Usually, in statistics, four types of correlations are measured: the Pearson correlation, the Kendall rank correlation, the Spearman correlation, and the Point-Biserial correlation. In this example, Spearman correlations were used.

Homestead Food Gardens Model

There are different and several agricultural sustainability models, to this end MESMIS (Management Systems Assessment Framework Incorporating Sustainability Indicators) was found to be relevant to this study. The model does the systems characterization, the critical points identification and the specific indicators selection for the sustainability of the social, environmental and economic dimensions. Obtaining information through indicators means it is integrated through mixed techniques (quantitative and qualitative) and the analysis of the multi-criteria (Cruz *et al.,* 2018). The MESMIS model, however, doesn't touch base on tangible issues such as innovations in the homestead food gardens production. Consideration of high-value crops, an initiative to take homestead food gardens to greater heights and to ensure that their commercialisation can be realised is thus critical. Plantation of crops with repellents and the capabilities in the households' food gardens would ensure maximisation of production since this action would curb the challenge of insect pests. The establishment of the central pack house which can accommodate neighbouring communities on their household production, is an initiative that will ensure commercialisation and market access.

RESULTS AND DISCUSSION

Households Socio-Economic Characteristics

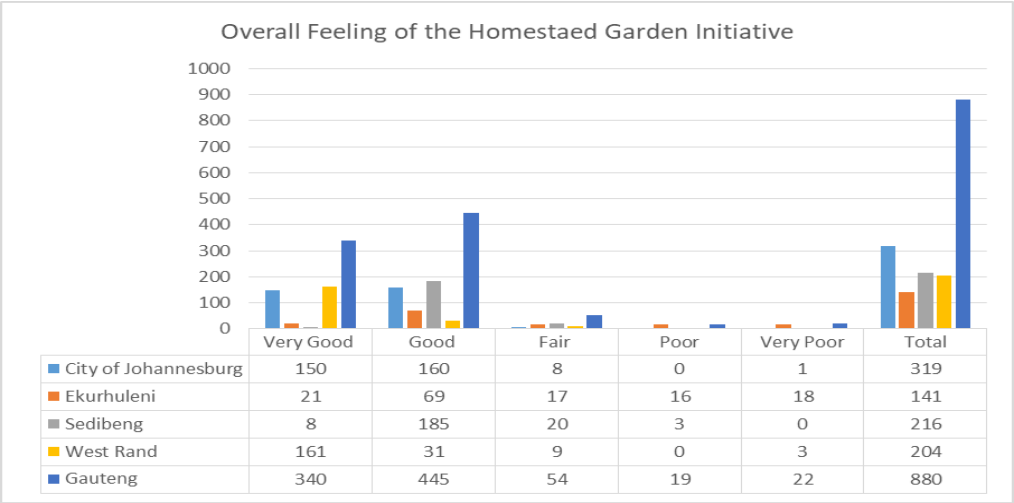
The majority of households interviewed were females (703) as compared to males (177) and this happened again in metropolitans and districts. Maponya and Moja (2012) indicated that in Limpopo Province, household females include a significant number of active populations economically and households headed by females usually fall within the categories of food insecure, marginal, and vulnerable categories. The results showed different households ages and most households were found in the age > 56 (320) and few households age fall in the category < 35 years (110). The same categories of age trends appear in districts and metropolitans. These trends show a need for youth involvement in the homestead garden programme as any agricultural future developments in the metropolitans and districts should attract youth.

When considering attainment of education, the majority of households obtained secondary education (449) and a few with tertiary education (21). The education level is consistent for all metropolitans and districts in the Province. Heckman (1999) indicates that education has proven to be key to improving household food security, reducing poverty and improving the poor's livelihoods.

The results also indicated that most households were found to be in income level of between R1001 – R2500 and the majority of households do not have income (150). On the spending, the majority of households' food expenditure were > R601 per month. It was further emphasised before the COVID-19 pandemic that between November 2015 and April 2017, the cost of a food basket comprising the most basic of items rose from R1 648.10 to R2 053.98 (PACSA, 2017). Items that are included in the basket focused on the staples that people buy on a monthly basis in order to service their food needs. These included starchy foods such as mealie meal and rice, vegetables like onions and cabbage, fruit such as oranges and bananas, dry beans, meat and poultry, milk, oils, sugars and salt. Currently, South Africans are paying nearly R300 more for the average food basket in May 2021 compared to 2020 September (PMBEJD, 2021). This is according to the latest Household Affordability Index report compiled by the Pietermaritzburg Economic Justice & Dignity Group (PMBEJD, 2021), which tracks food price data from 44 supermarkets and 30 butcheries in Johannesburg, Durban, Cape Town, Pietermaritzburg and Springbok in Northern Cape. The majority of household size were between members of 1 – 5 and the same trend is found across metropolitans and districts. Amaza *et al.,* (2009) indicated the importance of household size as it is contributing to food security through the provision of labour.

Homestead Food Garden Initiative

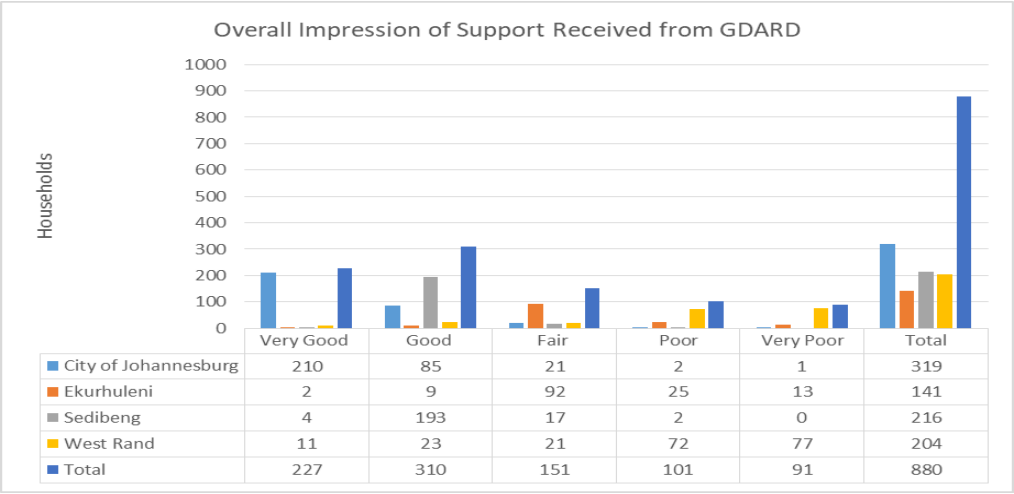
As indicated in Figure 1 many households felt that homestead food garden initiative is very good (340); good (445) and fair (54). Few households indicated that the homestead food garden initiative is poor (19) and very poor (22). Monitoring and evaluation of the initiative remained the challenge for some households.



	Very Good	Good	Fair	Poor	Very Poor	Total
City of Johannesburg	150	160	8	0	1	319
Ekurhuleni	21	69	17	16	18	141
Sedibeng	8	185	20	3	0	216
West Rand	161	31	9	0	3	204
Gauteng	340	445	54	19	22	880

Figure 1. Overall Feeling of the Homestead Garden Initiative.

As indicated in Figure 2 more households felt that the support received is very good (227), good (310) and fair (151). Furthermore, the majority of households had a feeling that the support received was poor (101) and very poor (91). A complaint from households about the monitoring and evaluation of the initiatives of the homestead was also registered as the reason for their fair, poor and very poor responses. The same scenario was also observed across metropolitan areas and districts. Hence, GDARD needs to make follow-up on this situation.



	Very Good	Good	Fair	Poor	Very Poor	Total
City of Johannesburg	210	85	21	2	1	319
Ekurhuleni	2	9	92	25	13	141
Sedibeng	4	193	17	2	0	216
West Rand	11	23	21	72	77	204
Total	227	310	151	101	91	880

Figure 2. Households' Overall Impression of Support Received.

Sustainability of the Homestead Gardens

In terms of *economic sustainability*, 733 of the households agreed that there is no income generation from the gardens. Furthermore, 147 households indicated that there are income generation from their gardens. This situation is against the benefits from some food gardens i.e. the household reduction on expenses for food purchase, and the income generation through the surplus produce sale. In terms of *social sustainability*, there is an equal response regarding social initiatives supported by the gardens: Yes (527 households) and No (353 households). HFG contribution of the gardens is noted very well towards social initiatives and should further be supported. In terms of environmental sustainability, the priority on environmental awareness should be prioritised by GDARD, as 701 households were not aware of the issues of the environment. Households should be trained about environmental benefits including waste nutrients and recycling water, erosion and dust, controlling shade, increasing or maintaining local biodiversity.

Correlations among variables

As indicated in Tables 1 and 2, there is a positive correlation between variables: household size/members and gardens still available. It is generally expected that employed household members can contribute to the household food intake either through being involved actively or through formal employment. Maponya et al. (2012) indicate that households that have financial resources with more members are more food secure as compared to those with less financial resources. As indicated in Table 1, there is a positive correlation between gender and garden still available. These results are in line with Ndobo *et al.* (2013) who cited that female-headed households are more likely to face moderate-to-mild as well as severe food insecurity forms than those of male-headed headed. Mohammadi *et al.* (2014) also reported severe food insecurity amongst households headed by females. The same study emphasised that there is a positive correlation between garden availability and age. As shown in Tables 1 and 2, both variables are significant at 5%. The results further indicate that any age category can participate in food gardening provided there is a garden available. As indicated in Tables 1 and 2, a positive correlation exists between gardens still available and income. It is expected that with garden availability an extra income can be achieved from surplus production. An increase in households' income can also reduce food insecurity. Maponya and Moja (2012) cited that the combination of production and income generation among households improves food security.

Table 1. Spearman Correlation Coefficients among Variables.

	GAR	GEN[2]	HOU[3]	AGE[4]	HOU1[5]
GAR	1.00	0.011*	0.040	0.027*	0.013*
GEN	0.011	1.00	0.009	0.180	-0.19
HOU	0.040	0.009	1.00	-0.76	-0.025
AGE	0.027	0.180	-0.76	1.00	-0.57
HOUI	0.013	-0.19	-0.025	-0.57	1.00

[1]Garden Still Available, [2]Gender, [3]Household Members, [4]Age, [5]Household Income
*5% Significant Level; **1% Significant Level

Table 2. Pearson's Correlation Coefficients among Variables.

	GAR[1]	HOU[2]	AGE[3]	HOU1[4]
GAR	1.00	0.052*	0.017	0.014**
HOU	0.052	1.00	-1.00	0.50*
AGE	0.017	-1.00	1.00	-2.85
HOUI	0.014	0.50*	-2.85	1.00

[1]Garden Still Available, [2]Household Members, [3]Age, [4]Household Income
*5% Significant Level; **1% Significant Level

CONCLUSIONS

It can be concluded that homestead food garden programme has a great potential. The study further established some challenges from the programme but is benefitting households in different ways: beneficiaries received seeds, tools and starter packs and using these resources to grow food which is augmenting households' income and nutritional intake. The study further established that some households are still gardening but the garden sustainability can be improved by: environmentally friendly techniques of soil improvement and control of pests; participation and involvement of the community in the design of homestead programme, regular water supply implementation and evaluation (information exchange two-way channels plays a role for improved achievements, garden sustainable practices); training and demonstrations, assistance, education in nutrition within the activities of gardening and monitoring are all important because it is used as a tool for making that the activities are carried out as planned and to improve the required performance. Furthermore, the results will facilitate the problem identification and solution development on sharing between the households and the Gauteng Department of Agriculture and Rural Development (GDARD). Correlations results indicated positive associations among the following variables: Availability of Garden, Household members, Age, Household Income and Gender. The study recommended the following activities to be improved in the programme: Communities and stakeholder mobilisation, situation analysis, food garden inputs, demonstration, training and technical assistance, educational nutrition, monitoring and evaluation and crop-based approach.

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The summary, in English language, should provide basic data on the problem that was treated and the results obtained. It should be brief, preferably one paragraph only, up to 250 words, but sufficient to inform the reader of the character of the work, its results and its conclusions.

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Material and methods explain how the study was carried: the organism(s) studied; description of the study site, including the significant physical and biological features, and the precise location (latitude and longitude, map, etc); the experimental or sampling design; the protocol for collecting data; how the data were analyzed. In this section also should be provided a clear description of instruments and equipment, machines, devices, chemicals, diagnostic kits, plants/animals studied, technology of growing/housing, sampling sites, software used, etc.

- RESULTS and **DISCUSSION**

Results and Discussion should be combined into a single section.

The results objectively present key results, without interpretation, in an orderly and logical sequence using both text and illustrative materials (tables and figures).

The discussion interpret results in light of what was already known about the subject of the investigation, and explain new understanding of the problem after taking results into consideration.

The International System of Units (SI) should be used.

- CONCLUSIONS

The conclusion should present a clear and concise review of experiments and results obtained, with possible reference to the enclosures.

- ACKNOWLEDGMENTS

If received significant help in designing, or carrying out the work, or received materials from someone who did a favour by supplying them, their assistance must be acknowledged. Acknowledgments are always brief and never flowery.

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