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Effect of yeast and mineral fertilisers on the level attack of the solenopsis mealybug and productivity okra plants

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Abstract: Mineral fertilisers are one of the most important nutrients that plants need in large quantities, which help to greatly increase crop yields, and yeast is considered a bio-stimulator of plants. However incorrect implementation of both can make them more susceptible to pest infestations. The mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae), is an economically important polyphagous pest that destroys okra plants in Egypt. This work focused on the evaluation of mealybug infestations and okra plant productivity responses to mineral fertilisers (nitrogen and phosphorus), yeast (without and with) and their interactions. This study was executed in a private okra field ('Balady' cultivar) in Luxor Governorate, Egypt, during 2021 and 2022 seasons. A split plot design was applied, where two levels (with and without yeast) were used in the main plots, where seven levels of nitrogen and phosphorus were applied in the split plots. The results indicated that the addition of 286 kg N·ha^{-1}, 143 kg P·ha^{-1} and yeast to okra plants led to a maximum increase in the population densities of pest, and this caused a decrease in the vegetative stage of okra that would affect the final yield as compared to the other treatments throughout the two seasons. However, the application of 190 kg N·ha^{-1}, 107 kg P·ha^{-1}, and yeast to okra plants gave the highest values for vegetative growth characteristics and resulting yield during the two studied seasons. This work aids farmers in improving okra production by comprehending good farming practices and avoiding the spread of mealybugs.

Keywords: good farming practices, nitrogen, phosphorus, vegetative characteristics

INTRODUCTION

Okra, also known as *Abelmoschus esculentus* L., is a well-liked vegetable that has a lot of vitamins and minerals, is widely available, and is a member of the Malvaceae family (Dantas *et al.*, 2021). It is mostly grown in several locations in Egypt and has a quick cycle.

Numerous piercing-sucking insect pests are able to damage okra plants (Shehata, 2017). One of the most dangerous pests that attack okra plants is the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) (Mohamed, 2021; Bakry and Fathipour, 2023). It is a little sap-sucking insect that seriously harms okra plants. All plant parts, including the leaves, branches, and fruits, are infested with this pest (Bakry, 2022; Bakry, Badawy and Mohamed, 2023). A sign of an infestation is the growth and aggregation of *P. solenopsis* bodies on the damaged plant parts (Shah, Ahmed and Memon, 2015). According to Fand and Suroshe (2015), the plants suffering from *P. solenopsis* infestations during their vegetative phase display symptoms of damage such as deformed shoots, crinkled and stunted plants, and, in extreme circumstances, entirely dried plants. *P. solenopsis* excretes honeydew, which promotes the growth of black sooty mould (Arif *et al*., 2012; Sahayaraj, Kumar and Avery, 2015), inhibits photosynthesis, and kills infected plants by causing chlorosis modifications, deformity, pits, and other symptoms (Ibrahim, Moharum and El-Ghany, 2015; Saad, 2021).

Various factors affect okra productivity, although agronomic practices are the main drivers of ideal growth and ultimate yield. To give plants optimal conditions for growth and development, they include choosing the right planting technique and mineral fertiliser levels, as well as minimising insect infestations during different growth stages (Yeboah *et al*., 2021). Chemical fertiliser utilisation is necessary for enhancing agricultural output while improving soil quality. However, improper or insufficient fertiliser application lacks the guarantee of constantly increasing yields, which might lead to inefficient nutrient use (Bisht and Chauhan, 2020). The deficiency of essential nutrients caused the crop growth to function poorly, which decreased production (Morgan and Connolly, 2013).

Regular application of chemical fertilisers typically results in a decline in the chemical, physical, and biological qualities of the soil, which in turn affects soil health. Long-term environmental contamination has also been a result of the continuous use of mineral fertiliser. Due to the detrimental impacts of chemical fertilisation and rising costs, interest in using organic manure as a source of nutrients, a substance that enhances crops, and a way to reduce costs and environmental damage has grown (Doklega, 2018).

Plant yields have also decreased as a result of a decline in the use of organic fertiliser as a source of plant minerals and soil enhancement due to the relative simplicity of application and quick effects of inorganic fertiliser use. When treated appropriately, biofertiliser (yeast) is among the most significant fertilisers since it has the potential to enhance the soil (Effa, Uko, and Nwagwu, 2018).

Organic fertiliser distributes nutrients gradually. When applied at the recommended rates, mineral fertilisers increase yield, whereas organic fertilisers enhance the chemical composition and quality of the okra. In comparison to other nutrients, NPK are the three most crucial nutrients that the plant needs (Akande *et al*., 2010). The combined use of mineral fertilisers and yeast has a more positive effect on okra plants than either mineral fertilisers or yeast used alone (Doklega, 2018).

Plants need nitrogen and phosphorus, crucial mineral elements for plant growth and development (Mohsen and Abdel-Fattah, 2015). Fertilisers are regarded as a consistent source of nutrients that increase crop productivity. Depending on the type of fertiliser used, the type of plant being grown, and the species of pests, the nature of these inputs may have an impact on pest populations (Ali *et al*., 2013). While balanced fertiliser is more prohibitively costly, multiple studies have shown that it is necessary for crop administration in order to get the best crop yield (Cui *et al*., 2018).

The effect of phosphorus fertiliser rates on okra plants was studied by El-Shaikh (2005) and El-Waraky (2014) who mentioned that the yield attributes exhibited the maximum values with the increase in phosphorus rate.

Insects that feed on phloem can have their diet levels of nitrogen altered by applying nitrogen fertiliser to the soil, which can affect the population growth of these insects (Godfrey *et al*., 1999). This also enhances plant nutritional status, direct pest resistance (Chen and Ruberson, 2008), decreased evaporation, and higher transpiration were also observed (Nangia, Turral and Molden, 2008).

Yeast as a bio-stimulator is characterised by its presence in protein, carbohydrates, lipids, nucleic acids, and some minerals (Reed and Nagodawithana, 1991). A bio-fertiliser contains living microorganisms like fungi, bacteria, and blue-green algae (Doklega, 2018). Bio-fertilisers are utilised as foliar applications to the soil and leaves of plants, colonising the rhizosphere at the roots to stimulate biological metabolism that enhances plant development and growth. By enhancing nutrient absorption, nitrogen fixation, the creation of organic acids, protection against plant infections, and excretion growth regulators like indole acetic acid (IAA) and gibberellic acid (GA3), bio-fertilisers may affect plant growth and productivity. By using bio-fertilisers, it is possible to reduce environmental pollution, increase the availability of various nutrients for plant absorption, improve plant resistance to root diseases, and restrict the amount of nitrogen that plants need by 25% (Kannaiyan, 2002). According to Mahmoud *et al*. (2013), foliar application of yeast extract at a rate of 2% improved all growth measurements, pea production, and pea quality. Additionally, Ibraheim (2014) discovered that when pea plants were treated with yeast extract, there were appreciable increases in total chlorophyll contents, N, P, Zn, protein, total sugars, and total soluble solids (TSS), as well as yield per feddan (4200 m^2), in comparison to the treatment without yeast.

It has not been investigated how agronomic practices affect *P. solenopsis* population dynamics. Therefore, the main objective of this study was to evaluate the possible impact of the application of different rates of mineral fertiliser (nitrogen and phosphorus) and two treatments (without and with yeast), as well as combined interactions on pest estimates when used with the 'Balady' okra cultivar in Luxor Governorate, Egypt. It is essential to comprehend these pest parameters in terms of the abundance, spread, and growth of the pest. The focus of this work was to evaluate mealybug infestations and okra plant productivity response to mineral fertilisers (nitrogen and phosphorus), yeast (with and without) and their interactions. In light of this, the primary objective of this study is to help farmers understand the proper agronomic practices for the okra crop in order to reduce *P. solenopsis* occurrence in okra plants.

MATERIALS AND METHODS

EXPERIMENTAL DESIGN

The trial was performed in a private okra field (25°17'16" N, 32° 34'32" E) throughout two growing seasons (2021 and 2022) at Esna District, Luxor Governorate, Egypt, to assess the influence of mineral fertilisers (nitrogen and phosphorus) utilisations with and without yeast on the mealybug infestation rates, vegetative growth characteristics of okra, and resulting yield. Over a location of approximately one feddan (4200 m^2), including experimental units, the okra plants ('Balady' cultivar) were transplanted.

Physical and chemical analyses of soil were analysed according to the World Reference Base for Soil Resources (IUSS Working group WRB, 2015). Table S1 contains information about the soil analysed during the February 2021 season.

A split-plot design using the randomised complete block approach was used to distribute each experimental unit, which was 10.5 m^2, i.e. (3 × 3.5 m) shaped to 6 ridges with a length of 3 m and a wide 0.5 m, with three replicates (plots). The main plots contained seven levels of nitrogen and phosphorus fertilisers, whereas the split plots contained two yeast levels (without and with yeast).

STUDIED FACTORS AND THEIR TREATMENTS

The study involved 14 treatments, which were the combination between two treatments (without and with yeast (5 $g \cdot dm^{-3}$)) and seven rates of nitrogen and phosphorus fertiliser (unfertilised soil, 190 kg $N \cdot ha^{-1}$ with 107 kg $P \cdot ha^{-1}$, 190 kg $N \cdot ha^{-1}$ with 143 kg $P \cdot ha^{-1}$, 238 kg $N \cdot ha^{-1}$ with 107 kg $P \cdot ha^{-1}$, 238 kg $N \cdot ha^{-1}$ with 143 kg $P \cdot ha^{-1}$, 286 kg $N \cdot ha^{-1}$ with 107 kg $P \cdot ha^{-1}$ and 286 kg $N \cdot ha^{-1}$ with 143 kg $P \cdot ha^{-1}$).

Calcium superphosphate (15.5% P_2O_5) was added during soil preparation. Ammonium sulphate rates (20.5% N) were divided into three equal parts. The first is applied a month after planting, the second when flowering appears, and the third is applied a month after each season.

Potassium sulphate fertiliser (48% K_2O) was also divided at a rate of 120 $K_2O \cdot ha^{-1}$ into three equal parts at the same times as nitrogen fertiliser was added (Doklega, 2018).

Five periods of yeast extract were carried out were sprayed on the plant surface. The first was applied one month after planting, and the subsequent dosages were applied every seven days.

The experiment consisted of 14 treatments, each of which had three replicates, for a total of 42 units. At a suitable time (first week of February for each season), the okra plants were planted. Without applying any pest control techniques, all other agronomic procedures were carried out in accordance with the advice of the Egyptian Ministry of Agriculture. The trial was irrigated with a surface irrigation system.

POPULATION OCCURRENCE OF THE MEALYBUG, *P. solenopsis* INFESTING OKRA PLANTS

The sampling date was established as the first mealybug invasion could be found in the study area. The mealybug outbreak started after a month after transplanting and extended into harvest. The total number of mealybugs was counted after 40 okra leaves were randomly chosen from each treatment every week (10 leaves from each plot). Individuals of mealybugs were kept in tubes filled with 90% alcohol until they were prepared for identification by the Egyptian Plant Protection Research Institute which has classified the insect.

The leaf samples came from various plant directions within each plot and were chosen at random. The gathered leaves were taken to the lab for analysis and transported there in polyethylene bags. On each investigation date under consideration, the total number of mealybugs on the two faces of the leaves was noted and counted. All of the plots under study carried this out. To discuss the seasonal occurrence of *P. solenopsis* based on the average number of populations per 10 leaves, monthly records on okra plants, plus or minus (±), and the standard error (*SE*) were used to assess population estimates.

Over the duration of two seasons, we acquired a total of 16,800 leaves at 40 different times. The total number of leaves used for sampling was 16,800 leaves (i.e. 10 leaves · 3 replicates · 14 treatments · 20 dates · 2 seasons). Each season 8,400 leaves were acquired.

VEGETATIVE GROWTH CHARACTERISTICS, RESULTANT YIELD AND ITS COMPONENTS OF OKRA PLANTS

The recorded data for vegetative growth attributes, yield and its components of okra plants were evaluated. Five plants were randomly selected at harvest time from every plot to gather the following characteristics: plant height (cm), number of branches per plant (pcs), number of green leaves per plant (pcs), number of fresh fruits per plant (pcs), mean fresh weight of fruit (g), yield (kg) per plot (10.5 m^2).

STATISTICAL ANALYSIS

A split-plot layout was utilised in the statistical analysis of the data, with three replicates. Using the SPSS Program (SPSS Inc, 1999), the means of the treatments were evaluated using the least significant difference test (LSD) at a 5% level of probability.

RESULTS

SEASONAL ABUNDANCE OF MEALYBUG (*Phenacoccus solenopsis*) INFESTING OKRA PLANTS

The data presented in Tables S2 and S3 showed that the total number of mealybug (*Phenacoccus solenopsis*) was observed on okra plants through the period from March to July in each season. June was the most proper month for *P. solenopsis* population estimates to increase (as estimated during monthly inspections), but March was the least proper for activity in all the studied treatments in both seasons.

The visual symptoms of *P. solenopsis* damage on the leaves, stems, and fruits of okra plants are shown in Photo 1.

Statistically, the analysis of variance noted the existence of significant changes in the population densities of *P. solenopsis* during the monthly examination times throughout each season in all assessed treatments when the comparisons were finished for each treatment individually.

As shown in Tables S2 and S3, the okra plants treated with the yeast increased the population counts of *P. solenopsis* by an average of 117.68 ±8.57 and 133.50 ±9.94 individuals per 10 leaves as compared to the plants untreated with the yeast (control – 108.89 ±8.07 and 124.33 ±9.29 individuals per 10 leaves) during the two seasons, respectively. Based on statistical analysis of the reported data, the average population of *P. solenopsis* between the two yeast treatments varied significantly (least significant difference test (*LSD*) values were 5.52 and 3.26 for the two seasons, respectively). Likewise, the coefficients of variation percentages were 6.62 and 11.88% in the two seasons, respectively.

Regarding the nitrogen and phosphorus fertiliser levels, the addition of nitrogen and phosphorus at a rate of 286 kg $N \cdot ha^{-1}$ + 143 kg $P \cdot ha^{-1}$ increased the numbers of *P. solenopsis* by an average of 159.06 ±7.09 and 182.14 ±13.84 individuals per 10

Photo 1. *Phenacoccus solenopsis* visual damage symptoms on leaves, stems, and fruits of okra plants (the photos were taken in the fourth week of June in the okra field experiment) (phot.: *M.M.S. Bakry*)

leaves, as compared with the fertilisation by 190 kg N·ha^{-1} + 107 kg P·ha^{-1} (68.18 ±2.29 and 76.31 ±5.59 individuals per 10 leaves), across the two seasons, respectively. Statistically, the various levels of nitrogen and phosphorus fertiliser significantly affected the mean populations of *P. solenopsis* (*LSD* values were 9.19 and 18.98) throughout the two seasons, respectively. In this context, the coefficients of variation values were 3.45 and 9.41% during the two seasons, respectively.

As for the influence of interaction between yeast and N + P fertilisers, the data mentioned that the interaction between yeast and N + P fertilisers appeared to have a significant impact on the population size of *P. solenopsis* throughout the two seasons (*LSD* values were 13.00 and 26.84, respectively). At the same time, the coefficients of variation percentage values were (6.81 and 12.35%) over the two seasons, respectively.

The highest population density was recorded using treatments Y1 + T7 (286 kg N·ha^{-1} + 143 kg P·ha^{-1} combined with yeast) with an average of 165.95 ±12.13 and 186.15 ±13.87 individuals per 10 leaves as compared to the other tested treatments. However, the lowest population of *P. solenopsis* was acquired in the treatments Y0 + T1 (190 kg N·ha^{-1} with 107 kg P·ha^{-1} uncombined with yeast) with an average of 67.90 ±4.91 and 75.83 ±5.56 individuals per 10 leaves when compared to the other tested treatments, respectively (Tables S2 and S3).

Furthermore, the average *P. solenopsis* size was significantly influenced by the interactions among yeast treatments, nitrogen and phosphorus fertiliser levels, and inspection intervals (*LSD* values of 17.56 and 25.65 for the two seasons, respectively). As well, the coefficients of variation percentages were 9.67 and 12.41% over the two seasons, respectively, as shown in Tables S1 and S2. As for the average total numbers of *P. solenopsis* during the second season, they were higher (128.91 ±4.13 individuals) as compared to the first season (113.28 ±3.54 individuals per 10 leaves).

THE EFFECTS OF THE APPLICATION OF MINERAL FERTILISERS (N + P) AND YEAST TREATMENTS ON OKRA VEGETATIVE GROWTH ATTRIBUTES AND EVENTUAL YIELD AND ITS COMPONENTS

Vegetative growth attributes

The acquired data showed that the vegetative growth measurements were influenced by the levels of mineral fertiliser and yeast treatments in the two investigated seasons (Tab. S4). The results appeared to indicate that the okra plants treated with the yeast increased all vegetative growth, i.e., plant height, number of branches per plant, compared with the plants untreated with yeast (control), during the two seasons, respectively. All the vegetative growth attributes between the two treatments (without and with yeast) of okra plants had significant variances over the two seasons.

The data showed that the effect of different levels of nitrogen and phosphorus on okra plants indicates that the addition of nitrogen and phosphorus led to an increase in all growth attributes; the treatment T2 using 190 kg N·ha^{-1} + 107 kg P·ha^{-1} gave the highest significant values in all vegetative growth attributes out of the other tested treatments during the two seasons, respectively. Also, there were significant differences between various nitrogen and phosphorus fertiliser rates in these attributes for each season of the study (Tab. S4).

It was clear that the highest values of the okra growth attributes were observed in the plants treated with yeast combined with 190 kg N·ha^{-1} and 107 kg P·ha^{-1} as compared to the tested treatments for the two seasons (Tab. S4). Although the increased treatments of N + P fertilisers and yeast (treatment 7 + Y1 – 286 kg N·ha^{-1} + 143 kg P·ha^{-1} with yeast) obtained the lowest growth values as compared to the plants treated with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} and yeast, this may be due to the application of 286 kg N·ha^{-1} + 143 kg P·ha^{-1} and yeast for plants as a result of increasing N + P fertilisers and yeast, which helped to increase the population counts of the insects, and this increase resulted in a reduction in all the vegetative growth characteristics of okra plants. Statistically, all okra growth parameters differed significantly due to the combined impacts of yeast with nitrogen and phosphate fertiliser levels in the two seasons (Tab. S4).

Okra resulting yield and its components

Through the documented data we can observe that the rates of yeast treatments and mineral fertiliser had an impact on the resulting yield and its attributes during the two investigational seasons (Tab. S5).

The findings appeared to show that over the two seasons, the okra plants treated with yeast enhanced all yield characteristics, i.e., number of fresh fruits per plant (pcs), fresh weight of fruit (g), and yield (kg) per plot, in comparison to the plants not treated with yeast (control). Over the two seasons, there were notable differences in all yield attributes between the two treatments (without and with yeast) for okra plants.

The data proved that various levels of nitrogen and phosphorus had a significant impact on okra plants, indicating that the addition of nitrogen and phosphorus increased all yield traits. The treatment T2, which used 190 kg N·ha^{-1} with 107 kg P·ha^{-1}, produced the highest values for all yield traits and their contents over the two seasons as compared to the other tested treatments. Additionally, there were notable variances in nitrogen and phosphate fertiliser rates in yield traits and okra final yield during the two seasons.

The plants treated with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} with yeast produced the highest yields of okra as compared to the other tested treatments. Whereas, the increasing treatments (286 kg N·ha^{-1} + 143 kg P·ha^{-1}with yeast) obtained the lowest values of the okra yield attributes in comparison to the plants treated with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} with yeast during the two seasons (Tab. S5).

This might be an effect of increasing N + P fertilisers with yeast, which would raise mealybug population counts, and this increase led to a decrease in all of the okra-productive traits (number of fresh fruits per plant (pcs), fresh weight of fruit (g), and yield (kg) per plot). As for the combined effects of yeast, nitrogen, and phosphate fertiliser levels, they resulted in statistically significant differences in all okra yield metrics between the two seasons (Tab. S5).

DISCUSSION

The mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) is a serious pest for many agricultural crops (Ricupero *et al.*, 2021). It is one of the most dangerous pests that attack okra plants (Mohamed, 2021; Bakry and Fathipour, 2023). *P. solenopsis* was observed on okra plants through the period from March to July in each season. Whereas, the average total numbers of *P. solenopsis* during the second season were higher as compared to the first season. June was the most proper month for *P. solenopsis* population activity to increase (as estimated during monthly inspections), but March was the least proper for activity in all the studied treatments in both seasons. The same findings were recorded by Bakry and Fathipour (2023) in Luxor, Egypt, who reported that June was the most favourable month for *P. solenopsis* population increase, while March was the least favourable for okra plants throughout the season. Bakry, Badawy and Mohamed (2023) mentioned that *P. solenopsis* infestation on okra plants emerged five weeks after planting and persisted until harvest in every season. Bakry, Mohamed and Shehata (2023) conducted a study that exhibited the significant role of the mealybug *P. solenopsis* in the decline of okra crop yield. They concluded that the level of infestation, the severity, and the susceptibility of okra plants to invasion were the most important contributing factors.

Treating the okra plants with the yeast resulted in increased population counts of *P. solenopsis* as compared to the plants not treated with the yeast (control) during the two seasons, respectively. The population counts of *P. solenopsis* may increase as a result of the carbohydrate accumulation and increased vegetative growth and cytokinin and auxin contents of the yeast-treated plants, providing favourable conditions for the growth and proliferation of the insect (Barnett, Payne and Yarrow, 1990). With regard to the impact of yeast, the amino acids, proteins, lipids, and carbohydrate hormones found in yeast can be used to increase growth factors and accelerate plant growth. These results coincide with those on okra plants reported by Wangchuk and Chhetri (2016).

Concerning the nitrogen and phosphorus fertiliser levels, the addition of nitrogen and phosphorus at a rate of 286 kg N·ha^{-1} + 143 kg P·ha^{-1} increased the numbers of *P. solenopsis* as compared with the fertilisation by 190 kg N·ha^{-1} with 107 kg P·ha^{-1}, across the two seasons, respectively. Also, the highest population density was recorded using treatments Y1 + T7 (286 kg N·ha^{-1} + 143 kg P·ha^{-1} combined with yeast) as compared to the other tested treatments. However, the lowest population of *P. solenopsis* was acquired in the treatments Y0 + T1 (190 kg N·ha^{-1} + 107 kg P·ha^{-1} not combined with yeast) when compared to the other tested treatments. The previous results coincide with past literature results demonstrating mealybugs prefer to feed on nitrogen-rich, juicy tissues. The survival, fecundity, and hatchability of sucking insects, as well as the ability of their eggs to hatch, were all enhanced by higher nitrogen content in host plants (Dogar *et al.*, 2018). Problems with these pests can result from excessive fertilisation and irrigation, as Goble, Wukasch and Sabourin (2012) highlighted (as cited in Dako and Degaga (2015), p. 34).

Regarding the vegetative growth attributes, yield and its contents. It was obvious that all vegetative growth traits and resulting yield attributes between the two treatments (without and with yeast) of okra plants had significant variances over the two seasons. This illustrates the increasing effect of the positive effect of yeast on metabolism, biological activity, and its stimulating effect on photosynthetic pigments and enzyme activity which in turn promotes vegetative growth (El-Sherbeny, Khalil and Hussein, 2007).

The data showed that the effect of different levels of nitrogen and phosphorus on okra plants indicates that the addition of nitrogen and phosphorus led to an increase in all growth and yield attributes; the treatment T2 using 190 kg N·ha^{-1} + 107 kg P·ha^{-1} gave the highest significant values in all vegetative growth and yield attributes out of other tested treatments during the two seasons, respectively. Also, there were significant differences between various nitrogen and phosphorus fertiliser rates in these attributes for each season of the study. It was clear that the highest values of the okra growth attributes and resulting yield were observed in the plants treated with yeast combined with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} as compared to the tested treatments for the two seasons. Although the increased treatments of N + P fertilisers and yeast (treatment 7 + Y1 – 286 kg N·ha^{-1} + 143 kg P·ha^{-1} with yeast) obtained the lowest growth and yield traits values as compared to the plants treated with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} with yeast, this may be due to the application of 286 kg N·ha^{-1} + 143 kg P·ha^{-1} with yeast for plants as a result of increasing N + P fertilisers with the yeast, which helped to increase the population counts of the insects, and this increase resulted in a reduction in all the vegetative growth characteristics and resulting yield of okra plants.

The results are in agreement with earlier literature results which mentioned that mineral fertiliser usage can influence the physiological, biochemical, and morphological characteristics of host plants (Simpson and Simpson, 1990). Increased use of nitrogen fertilisers encourages pest infestation of crops (Ge *et al*., 2003).

According to Mohsen and Abdel-Fattah (2015), the application of various quantities of fertiliser containing nitrogen, phosphorus, and compost, with or without compost, significantly ($p \leq 0.05$) affected the growth, yield, and other characteristics of okra plants. According to Palm, Myers and Nandwa (1997), both organic and inorganic fertilisers are crucial inputs for the cultivation of okra. One of the most crucial methods for improving okra production is the use of fertiliser at the right rate, and phosphorus fertiliser has a significant impact in this regard (Riasat *et al*., 2022). By encouraging root growth, phosphorus aids in nutrient uptake and ensures a strong pod output by increasing total dry weight per plant (Sharma and Yadav, 1997). Decreased root development, reduced pod setting, and decreased production are all consequences of phosphorus shortages (Jain *et al*., 1990).

Nitrogen and phosphorus are essential for plant growth and photosynthesis. Nitrogen promotes vegetative growth and is part of the chlorophyll molecule, which gives plants their green colour. Phosphorus is involved in metabolic processes and is critical for root development and flowering (Mohsen and Abdel-Fattah, 2015). According to Mal *et al*. (2013), the best yield of okra was also obtained when treated with biofertilisers, followed by mineral fertilisers. In a similar vein, Mal, Mahapatra and Mohanty (2014) mentioned that applying biofertilisers along with the necessary NPK levels to okra plants would be advantageous for vegetative growth, fruit output, and economics. Also, Sharma, Samnotra and Kumar (2014) and Wangchuk and Chhetri (2016) recommended that the application of bio-fertilisers in conjunction with mineral fertilisers had an impact on the growth and yield characteristics of okra. Khandaker *et al*. (2017) mentioned that N and P fertilisers are essential for enhancing plant development, the production of chlorophyll, and chemical composition, all of which have an impact on the yield and quality of okra.

The results exhibited that adding different levels of nitrogen with phosphorus fertilisers combined with or without yeast had a significant effect on the mealybugs' estimates, okra growth, yield and other attributes. This work helps farmers improve okra production by internalising good farming practices and avoiding the spread of mealybugs.

CONCLUSIONS

Based on the above-mentioned discussion during the two growing seasons, it could be concluded that the use of 286 kg N·ha^{-1} + 143 kg P·ha^{-1} with yeast gave okra plants the highest population densities of pest, whereas, the plants treated with 190 kg N·ha^{-1} + 107 kg P·ha^{-1} with yeast produced the highest vegetative growth characteristics and resulting yield of okra as compared with the other tested treatments during the two studied seasons. Adding varying amounts of nitrogen and phosphorous fertilisers, with or without yeast, is critical to enhancing growth and yield of okra. As a result, the addition of yeast leads to a significant increase in both vegetative growth and yield characteristics.

SUPPLEMENTARY MATERIAL

Supplementary material to this article can be found online at https://www.jwld.pl/files/Supplementary_material_Bakry.pdf

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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