Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.7, No.19, 2017

Effect of Biofertilizer and Plant Spacing on Growth, Yield and Fruit Quality of Brinjal (Solanum melongena L.)

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Abstract
A field experiment "effect of biofertilizer and plant spacing on growth, yield and fruit quality of brinjal" was carried out. Four Biofertilizer levels (B_1:0, B_2: 6.5, B_3: 8.5 and B_4: 10.5L ha^{-1}) and four Plant spacing (S_1: 60×30, S_2: 60×60, S_3: 60×90 and S_4: 60×120cm) were used. A Randomize Complete Block Design (RCBD) with split-plot arrangement was used in such a way that biofertilizer levels were subjected to main plots and plant spacing was allotted to sub plots. Biofertilizers and plant spacing significantly ($P \leq 0.05$) affected most of the attributes studied. Among the Biofertilizer treatments, maximum plant height (108.72cm), number of leaves $plant^{-1}$(135.33), leaf area (90.73cm^2), fruit weight (99.36gm), yield $plant^{-1}$ (1.77kg), total yield (37.21tons ha^{-1}), fruit pH (5.59), vitamin C (3.00mg) and fruit firmness (2.06kg cm^{-2}) were recorded in biofertilizer application @6.5L ha^{-1}. In case of different plant spacing maximum plant height (102.35cm), number of leaves $plant^{-1}$ (123.45), leaf area (86.41cm^2), fruit weight $plant^{-1}$ (89.54gm), yield $plant^{-1}$ (1.63kg), total yield (40.64tons ha^{-1}), fruit pH (5.44), vitamin C (2.70mg) and fruit firmness (2.05kg cm^{-2}) were recorded in 60x60 cm. It is concluded that biofertilizer application @6.5 L ha^{-1} with plant spacing 60x60 cm increased the qualitative and quantitative attributes of brinjal.
Keywords: Brinjal, biofertilizer, plant spacing, growth, yield, quality.

1. INTRODUCTION

Brinjal (*Solanum melongena* L.) belongs to solanaceae family, mostly grown in sub-tropics and tropics region of the world. It is broadly cultivated in Pakistan, China, India, Philippines, Bangladesh, Egypt, France, Italy, Middle East, Far East and U.S.A. (Yousafi *et al*, 2013). It is a rich source of vitamins (B, C, B6), copper, minerals, protiens, niacin, folate, and dietary fibers (Matsubara *et al*., 2005). Its production in Pakistan is 88.14 thousand tones and it occupies 91,014 hector (FAO, 2012). In KPK, annual production of brinjal is about 13.6 k tones in 9044 ha (Minfal, 2013). Brinjal is a good source of income for the farmers due to its high production and low cost of cultivation as compared to other vegetables (Aliyu *et al*., 1992). They are using chemicals fertilizers excessively for gaining higher production, and management of pest and diseases. These practices have led to health hazards, water and environmental pollution and detoriate the soil fertility to a considerable extent. The ever increasing costs of chemical fertilizers and pesticides have also emphasized the need for exploitation of bio fertilizers. Bio fertilizers are eco-friendly, low cost input and not only improved the crop growth and yield but also improve fruit quality (Kashyap *et al.*, 2014).

In Agriculture, bio fertilizers have developed recently as a promising part of integrating nutrient supply system. Our entire agriculture system depends in numerous ways on microbial activities and these microbes play a key role in increasing the yield. These microbiological manures are environment friendly and therefore protect the water, air and land pollution (Karmakar *et al*., 2007). Bio fertilizers are adequate to generate enviable results as compared to chemical fertilizers as each gram of carrier of bio fertilizers contains no less than 10 million feasible cells of a particular strain (Anandaraj and Delapierre, 2010). In non-leguminous crops, biofertilizers such as Azotobacter/Azospirillum are the most vital N-fixing bacteria. Under proper conditions, Azotobacter and Azospirillum can improve plant growth and yield of numerous agricultural crops in different conditions of soil (Okon and Gonzalez, 1994).

For optimum growth and yield, plants need proper nutrients and sunlight which could only be possible by proper plant spacing. Proper plant spacing had a greater impact on plant growth and yield (Gopalakrishnan, 2007). Brinjal require a proper planting distance for better yield and quality. The results of Degri *et al*. (2014) showed that closely spaced plants (60 x 20 cm and 60 x 30 cm) had a significantly higher pest population, higher shoot and fruit damage, the lower fruit number and fruit yield than wide spaced plants (60 x 40 cm and 60 x 50 cm). Brinjal farmers can therefore adopt the practice of spacing the plants at (60 x 40 cm) to minimize plants infestations by shoot and fruit borer and improve the production of brinjal. Keeping these facts in view the current studies were attempted to find the best possible level of biofertilizer for brinjal crop and the best plant spacing for higher production and quality of brinjal.

2. MATERIALS AND METHODS

A research was carried out to study the effect of bio fertilizer and plant spacing on growth, yield and fruit quality of brinjal at the Horticulture research farm, The University of Agriculture, Peshawar, during summer 2015. The experiment was laid out in Randomize Complete Block Design (RCBD) with split-plot arrangement in such a way that bio fertilizer (0, 6.5, 8.5, 10.5 L ha^{-1}) were subjected to the main plot and plant spacing (60 x 30, 60 x 60, 60 x 90, 60 x 120 cm) were allotted to sub plots.

2.1. Bio fertilizer stock solution preparation and application

Bio fertilizer (feng shou®) (Tiens Company) contains 5.9 x 10^7 cfu/ml Azotobactor and 1.3 x 10^7 cfu/ml of Azospirillum. A stock solution was prepared at the ratio of 1:100 in such a way that 1 lit of bio fertilizer were added to 100 lit of water and kept it for 30 min before application for enhancing microbial activities and to make colonies. At this ratio bio fertilizer was calculated for different plots and was applied after the transplantation of seedlings from the nursery.

2.2. Nursery raisings

Brinjal nursery was raised, under low plastic passage. Seeds (Shengyaun cultivar) were sown in pots which contain leaf litter, silt and garden soil in 1:1:1 and watered frequently with sprinkler. When the seedlings produced 4 to 6 leaves, they were transplanted into the well prepared plots which were subjected with different bio fertilizer levels and plants spacing. All the cultural practices were kept constant throughout the experiment.

2.3. Soil detail study

Experimental field was tested for soil analysis before transplantation which constitute N: 0.041 %, P: 8.71 mg kg^{-1}, K^+: 103 mg kg^{-1}, O.M: 0.77 %, pH: 7.6 with a textural class: Clay loam.

2.4. Recorded parameters over the span of study

Data concerning the brinjal plant growth, yield and quality variables were recorded from randomly selecting five plants in each treatment and their mean was then calculated. Plant height was measured from the base of the stem to the tip of the main stem. Number of leaves $plant^{-1}$ was observed by counting all the number of leaves. Leaf area was measured by leaf meter. Fruit weight (g) and yield $plant^{-1}$ (kg) was noted by using digital balance. Total Yield (tons ha^{-1}) was recorded by using the following equation:

$$Total\ yield(tons\ per\ ha) = \frac{Total\ yield\ per\ plot}{Total\ plot\ Area} \times 10{,}000$$

The vitamin C (mg) content of brinjal fruit juice was determined by method as mentioned in AOAC (2000). The fruit pH was determined after harvesting with help of an electronic pH meter (Jan *et al*., 2012). Fruit firmness was dictated by using Penetrometer (Pocharski *et al*., 2000).

Analysis of variance technique was used to analyse the recorded data followed the procedure of Jan *et al*. (2009). Least significant differences (LSD) test was applied by using PC program, Mstatistix 8.1 for the treatments separation and differences were observed in their interaction means.

3. RESULT AND DISCUSSION

3.1. Plant height (cm)

A highly significant effect was recorded between Bio fertilizer and plant on plant height (figure 01). Maximum plant height (113.62 cm) were seen in B_2 (biofertilizer application @ 6.5 L ha^{-1}) and S_2 (60 x 60 cm), followed by (111.23 cm) in B_2 @ 8.5 L ha^{-1} and S_3 (60 x 90 cm). Meanwhile, the smallest plant height (86.95 cm) was remarked in B_1 (control) and S_2 (60 x 60 cm).The finding was similar to the results of Kamili *et al.* (2002) who reported that brinjal plant height increased with the increasing of bio fertilizers rates. Our results were also in line up with that of Prabhu *et al.* (2003) they revealed that the application of organic and bio fertilizer rate directly help in increasing plant height, which might be due to the nutrient uptake of plants, that is important to improved chlorophyll content, carbohydrate synthesis and increased the activity of hormones. Brinjal plants height relied on plant spacing and both are inversely proportional to each other. Maloof *et al.* (2000) observed that brinjal plant height increases when plants were closer to each other and competes for resources.

3.2. Number of Leaves $plant^{-1}$

The mean data concerning to number of leaves $plant^{-1}$ are demonstrated in figure 02 , which was significantly affected by different rates of bio fertilizer, plant spacing and their interaction. Highest values (140.27 $plant^{-1}$) was noticed in B_2 (biofertilizer application @ 6.5 L ha^{-1}) and S_2 (60 x 60 cm) plant spacing, followed by (137.57 $plant^{-1}$) in B_2 (biofertilizer application @ 6.5 L ha^{-1}) and S_3 (60 x 90 cm). Moreover, the lowest number of leaves (90.77 $plant^{-1}$) was observed in B_1 (control) and S_1 (60 x 30 cm). Bio fertilizer and plant spacing have a good effect on the number of leaves $plant^{-1}$. Our observations were similar to Wange and Kale (2004) suggested that

increasing of bio fertilizers rates, tend to increase the leaves plant^{-1} as compared to control. That difference was because of the accessibility of nutrients which might have good impact on soil and water holding ability as mention by Roe and Cornforth (2000). Our results are in agreement with Badi *et al.* (2004) that nearer plant spacing showed a significant effect in the number of leaves which in turn produce fresh and dry mass much higher.

3.3. Leaf area (cm^2)

Leaf area of brinjal plants are given in table 01 suggests that different rates of bio fertilizer and spacing had a significant effect on leaf area, while its interaction was non significant. The mean data revealed that maximum leaf area (90.73 cm^2) was recorded in B_2 (biofertilizer application @ 6.5 L ha^{-1}), followed by (87.24 cm^2) in B_3 (biofertilizer application @ 8.5 L ha^{-1}). However, the minimum leaf area (74.33 cm^2) was noted in B_1 (control). For plant spacing the maximum leaf area (86.41 cm^2) was observed in S_2 (60 x 60 cm), followed by (86.32 cm^2) in S_3 (60 x 90 cm). Meanwhile, the least leaf area (78.31 cm^2) was recorded in S_1 (60 x 30 cm). These results are supported by Marschner (1986) who stated that there is a close relation between bio fertilizers and leaf area, increasing of bio fertilizers also increase the leaf area expansion and lead to increase the photosynthesis and yield. Findings are also in harmony with Papadopoulos and Ormrod (1990) who reported that decreasing the spacing between plants also reduced the leaf area.

3.4. Fruit Weight (g)

Mean data related to fruit weight is presented in figure 03, showed that plant spacing and bio fertilizer had a significant effect on fruit weight and its interaction was also observed significant. The figure (03) indicated that the maximum fruit weight (104.19 g) was recorded in B_2 (@ 6.5 L ha^{-1}) and S_2 (60 x 60 cm), followed by (102.81 g) at B_2 (@ 6.5 L ha^{-1}) and S_4 (60 x 120 cm). Although the minimum fruit weight (68.03 g) was noted in B_1 (control) and in S_1 (60 x 30 cm).These results were close to the findings of Wange and Kale (2004) who observed that the recommended dose of bio fertilizers application resulted in increased fruit weight, plant height and number of leaves plant^{-1} of brinjal, and also with Raj *et al.* (2001) who investigated that fruit weight is also effected by bio fertilizer increasing level. The research findings were same to Kogbe (1983) and Hanna *et al.* (1987) they recorded that the number of fruits and its fresh biomass (g) plant^{-1} increased with normal plant spacing in both brinjal and cucumber.

3.5. Yield plant^{-1} (kg)

Mean data regarding yield plant^{-1} in table 01, cleared that bio fertilizer and plant spacing have a significant effect on yield plant^{-1}, while their interaction was observed to be non significant. Statistical data in table 01 showed that among bio fertilizer, highest yield (1.774 kg) were recorded in B_2 (biofertilizer application @6.5 liter ha^{-1}), which is statistically at par with B_4 (biofertilizer application @10.5 liter ha^{-1}) having yield plant^{-1} (1.526 kg), followed by B_3 (biofertilizer application @8.5 liter ha^{-1}) which is (1.449 kg) whereas lowest data were recorded (1.132 kg) in B_1 (control). The data regarding plant spacing means showed that maximum (1.771 kg) yield plant^{-1} were found in S_3 (60 x 90 cm), which is statistically similar to S_4 (60 x 120 cm) having (1.751 kg) yield plant^{-1}, while minimum (0.725 kg) were observed in S_1 (60 x30 cm). Higher yield in bio fertilizer @ 6.5 L ha^{-1} might be due to higher nutrient supply and proper plant spacing when compared with other bio fertilizer rates and plant spacing where a significant reduction was observed. While in control plot the low yield plant^{-1} might be due to low nutrients availability or nutrient stress, which greatly affects the plant performance and lower the yield plant^{-1}. Mbagwu and Ekwualor (1990) reported that the soil physical characteristic improved, due to the use of organic matters which helps in enhancing the overall crop growth and yield. Mirzakhani *et al*. (2009) mentioned that the nitrogen availability in soil would be improved by azotobacter, which might have increased the yield.

3.6. Total Yield (tons ha^{-1})

Mean data regarding yield is demonstrated within table 01 which showed that bio fertilizer and spacing have a significant effect on total yield, though their interaction was observed to be non significant. In case of bio fertilizer rates, highest total yield (37.21 tons ha^{-1}) was observed in B_2 (biofertilizer application @6.5L ha^{-1}), followed by (32.06 tons ha^{-1}) at B_4 (biofertilizer application @10.5 L ha^{-1}) and the lowest yield was noticed (210.50 tons ha^{-1}) for B_1 (control). Data regarding plant spacing revealed that maximum total yield (40.64 tons ha^{-1}) were recorded in S_2 (60 x 60 cm), nearly followed by (30.45 tons ha^{-1}) in S_3 (60 x 90 cm), while the minimum total yield (24.0 tons ha^{-1}) were observed in S_1 (60 x 30 cm). Singh *et al*. (2008) mentioned that highest fruit yield was recorded by the application of azotobacter and nitrogen in tomato (*Lycopersicon esculentum*). Our findings are also in line with Tripathi *et al*. (2010) and Wange *et al*. (1998) who recorded maximum yield in strawberry with phosphorous solubalizing bacteria (PSB) and Azotobacter application. The findings of our experiment related to yield were close to that of Nasiah (2009) who recorded the highest number of fruit plant^{-1} in (70 x 70 cm) and highest fruit weight of brinjal (*Solanum melongena* L.) at (70 x 50 cm)

3.7. Fruit pH

Figure 04 indicated a significant interaction between biofertilizers and plant spacing on fruit pH. Highest data was observed (5.99) in B_2 (biofertilizer application @6.5 L ha^{-1}) and S_2 (60 x 60 cm) which is statistically at par from B_3 (biofertilizer application @8.5 L ha^{-1}) and S_3 (60 x 90 cm) which is (5.91), while the lowest was noted (10.51) in B_3 (biofertilizer application @8.5 L ha^{-1}) and S_3 (60 x 90 cm). Our results are in conformity with Akanbi *et al*. (2007) who examined the effect of bio fertilizer on fruit pH, number and crude protein, total solids and ascorbic acid in brinjal and recorded the highest fruit pH due to phytohormones and other nutrients because of the application of biofertilizer. Similar findings were also reported by Dafigan and Abak (2003) who suggested that plant spacing and shoot numbers did not influence fruit quality, such as fruit dry matter contents, total soluble solids and the pH of the flesh in any cultivar of brinjal.

3.8. Vitamin C (mg)

Mean data regarding vitamin C of brinjal fruits are demonstrated within table 01, clearly showed that bio-fertilizer have significant effect on vitamin C, though plant spacing and its interaction have discovered non significant. Mean facts in the table 01 revealed that greatest values (3.00 mg) of vitamins C were recorded in B_2 (biofertilizer application @ 6.5 L ha^{-1}), followed by (2.81 mg) in B_3 (biofertilizer application @ 8.5 L ha^{-1}), and the lowest vitamin C (2.07 mg) was noticed in B_1 (control). Our investigation was supported by Unlu *et al*., (2010) and Wuzhong (2002) who suggested that both bio fertilizers application and humic acid affect the concentration of vitamin C and the amount of antioxidative compounds in solanaceous crops. Our finding were also analogous to the observations of Mohammad *et al.* (2012) who reported that nitrogen fertilizer have an effect on plant vitamin C, the increasing rate of nitrogen fertilizer improved the plant vitamin C contents.

3.9. Fruit Firmness (kg cm^{-2})

The records related to firmness of fruit are cleared in figure 05 as affected by biofertilizers and plant spacing. Highest (2.33 kg cm^{-2}) fruit firmness was recorded for B_3 (biofertilizer application @8.5 L ha^{-1}) followed by (2.27 kg cm^{-2}) for B_2 (biofertilizer application @6.5 L ha^{-1}) at S_4 (60 x 120 cm) and B_4 (biofertilizer application @10.5 L ha^{-1}) at S_3 (60 x 30 cm), while the minimum (1.64 kg cm^{-2}) fruit firmness was recorded for B_1 (control) at S_1 (60 x 30 cm). Present results are similar to that of Mishraf *et al*. (2000) and Suge *et al*. (2011) who stated that both bio fertilizers and basic micro and macronutrients are good for plant fruit firmness and natural soil texture. Moreover, Grierson and Kader (1986) who reported that plant spacing and bio fertilizers have good effect on fruit firmness of brinjal plant and close plant spacing (15 x 10 inches) and (20 x 10 inches) increased the firmness.

4. CONCLUSIONS

Results obtained from the present exploration work, concluded that both biofertilizer and plant spacing showed a significant effect on quantitative and qualitative attributes of brinjal. Application of biofertilizer @6.5 L ha^{-1} and plant spacing 60 x 60 cm showed positive impact as compared to other levels of biofertilizer and plant spacing. Further investigation should be conducted on the application of biofertilizer with different rates of organic fertilizer for better production and improved quality of brinjal.

Table 01: Effect of biofertilizer and plant spacing on the growth, yield and quality of brinjal

Characters	Leaf area (cm)	yield plant(kg)	total yield(tons ha)	vitamin C (mg)
Biofertilizer L ha-1				
Control	74.33 b	1.13 c	210.50 c	2.07
6.5	90.73 a	1.77 a	37.21 a	3.00
8.5	87.24 a	1.45 bc	31.06 b	2.81
10.5	84.92 a	1.53 ab	32.06 ab	2.64
LSD	6.14	0.32	6.09	0.19
Plant spacing (cm)				
60 x 30	78.31 b	0.73 b	29.75 b	6.53 b
60 x 60	86.41 a	1.64 a	40.64 a	2.70 a
60 x 90	86.32 a	1.77 a	30.45 b	2.61 ab
60 x 120	86.18 a	1.75 a	24.00 b	2.68 ab
LSD	4.62	0.44	8.48	NS

Means followed by same letters in the columns are statistically not similar at ($P \leq 0.05$).

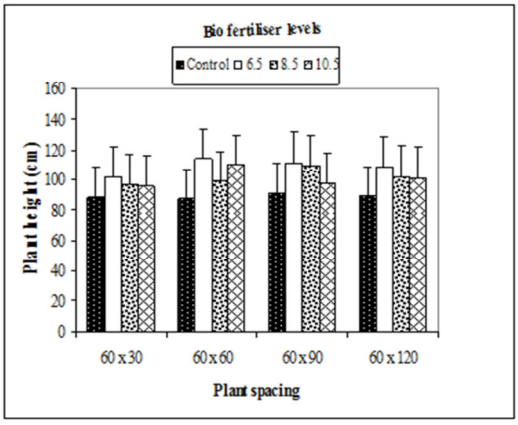

Figure 01: Effect of biofertilizers and plant spacing on plant height (cm).

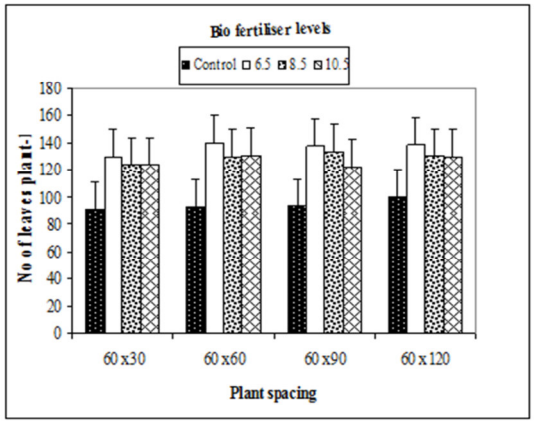

Figure 02: Effect of biofertilizers and plant spacing on Number of leaves plant^{-1}.

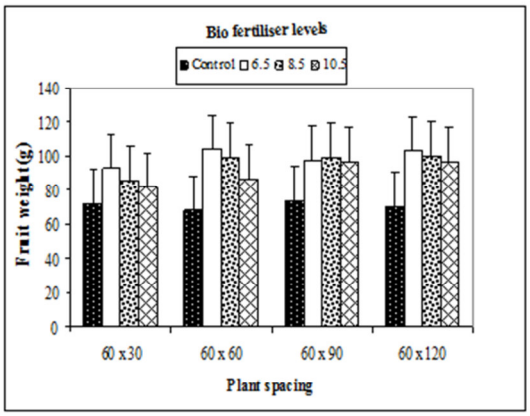

Figure 03: Effect of biofertilizers and plant spacing on fruit weight (gm).

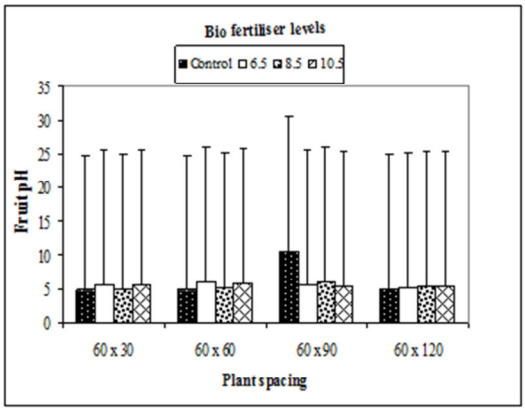

Figure 04: Effect of biofertilizers and plant spacing on fruit pH.

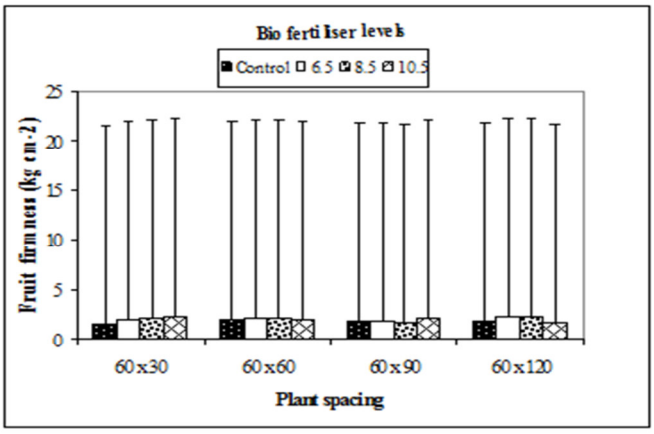

Figure 05: Effect of biofertilizers and plant spacing on fruit Firmness (kg cm^{-2}).

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