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Impact of crop geometry and fertilizer doses on the population density of insect-pests on pole bean (*Phaseolus vulgaris* L.) under net house conditions

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ABSTRACT: Studies were conducted on the incidence of major pests *viz*. serpentine leaf miner, spider mite, leafhopper, and tobacco cutworm of pole bean in relations to the crop spacing and fertilizer application, during *rabi* 2019-20. Spacing between crops and nutrient nourishment distinctively governed the activity of insect pests in pole bean crop (*Phaseolus vulgaris* L.), grown under the net house. It was revealed from the study that when the crop was raised at a wider spacing of 45×60 cm with fertigation of 125% RDF (Recommended dose of fertilizer) (78.12:125:93.75 NPK kg per ha) resulted in the lowest population density of the infesting insect whereas the highest at the interaction of 45×30 cm spacing and 75% RDF (46.87:75:56.25 NPK kg per ha).This suggested that a wider spacing and increased dose of recommended fertilizer could lessen the pest population and vice-versa conditions could increase it. Hence it can be a non-chemical implication for the management of insect-pest under the net house.

Keywords: Pole bean, spacing, fertilizer dose, population density, *Phaseolus vulgaris,* nutrient, net house.

INTRODUCTION

Pole bean (*Phaseolus vulgaris* L.) belonging to the family Fabaceae is an important pulse crop. It is also known as French bean, common bean, green bean, kidney bean, snap bean, etc. It is either bush type or pole type depending on the growth habit of the French bean. Because of their typical ways of growing on "tepees" built of bamboo poles or branches to form a twisting vine, they are called "pole beans". It is cultivated mostly for the tender pods, and dry beans. The dried beans are rich in protein, vitamins, and minerals. It has some medicinal properties for controlling diabetes, cardiac problems, and is a natural cure for bladder burn diseases (Duke, 1982). In India, beans are mostly grown in Gujarat, Jharkhand, Tamil Nadu, Karnataka, Uttar Pradesh, and Andhra Pradesh.

Insect pests are a major threat to pole bean, as they affect both quality and quantity of yield. The balance and quality of nutrition in plants matter a lot and are key characteristics for the selection by phytophagous insects as their host (Bernays and Chapman, 1994).Insect's nutritional values include carbohydrates, proteins, amino acids, fatty acids, minerals, and vitamins and they obtain these nutrients by feeding on plants. Therefore plant nutrition and its availability to insects is very important, to use as a strategy for restraining phytophagous insects. Plant spacing is also a key feature of crop diversification that needs to be looked into so that potential and viable IPM programs can be established (Sujay and Giraddi, 2014).

Since, pole bean is being newly introduced in Karnataka especially in North Karnataka, so the present study was therefore undertaken to know the effect of the fertigation and different spacing levels on the crop which was grown under net house condition.

MATERIALS AND METHODS

Studies were conducted under the net house, during rabi 2019-20, at Hi-tech Horticulture Unit, UAS, Dharwad (15.4889˚N, 74.9813˚E).The experiment was laid out on a factorial RCBD design with three levels of spacing (P_1: 45×30cm, P_2: 45×45cm, P_3: 45×60cm) and also three levels of fertigation (F_1: 100%RDF- 62.5: 100: 75 NPK kg/ha, F_2: 125% RDF -78.12: 125: 93.75 NPK kg/ha, F_3: 75% RDF- 46.87:75:56.25 NPK kg/ha). Nine treatments (Table 1) with three replications were carried out on beds measuring 35x1m each. The pole bean crop was raised according to the standard agronomic practices. The experimental area was kept free from any insecticidal spray.

Method of recording the population of insect pests

In case of recording for the population of sucking pests *viz.,* spider mite, *Tetranychus urticae* Koch and hoppers,

Table 1. Details of the treatments

Treatment (T)	Crop geometry and fertilizer dosage
$T_1 = P_1F_1$	45 cm× 30 cm + 100% RDF
$T_2 = P_1F_2$	45 cm× 30 cm + 125% RDF
$T_3 = P_1F_3$	45 cm× 30 cm + 75% RDF
$T_4 = P_2F_1$	45 cm× 45 cm + 100% RDF
$T_5 = P_2F_2$	45 cm× 45 cm + 125% RDF
$T_6 = P_2F_3$	45 cm× 45 cm + 75% RDF
$T_7 = P_3F_1$	45 cm× 60 cm + 100% RDF
$T_8 = P_3F_2$	45 cm× 60 cm + 125% RDF
$T_9 = P_3F_3$	45 cm× 60 cm + 75% RDF

RDF – Recommended dose of fertiliser; NPK- Nitrogen-Phosphorus-Potassium; P_1, P_2, P_3 – Levels of crop spacing; F_1, F_2, F_3 - Levels of fertigation; 100% RDF -62.5: 100: 75, 75% RDF -46.87:75:56.25, 125% RDF-78.12: 125: 93.75 NPK kg/ha

Ianagallia bifurcate Sawai Singh and Gill, five plants were selected randomly from each plot (Gupta *et al*., 2016). The population of those insects was recorded on three leaves selected randomly from the top, middle, and bottom canopy from the selected plants. For recording of leaf miner, *Liriomyza trifolii* Burgess population, five leaves from randomly tagged five plants from each plot were collected and number of larvae present in the mines were recorded. The population abundance of tobacco caterpillar, *Spodoptera litura* F, was assessed by counting the number of larvae observed per meter length in five randomly selected spots per plot. All the observations were taken at weekly intervals starting from the first visible incidence of insect on the crop to harvesting it.

Method of application of fertilizer

Fertilizer doses were applied according to the treatments (Table 1) by fertigation method, through drip irrigation system for even distribution. The first fertigation was given at 20 days after sowing then at weekly intervals up to flowering of the crop.

RESULTS AND DISCUSSION

Both crop geometry and fertilizer dose influenced the population of the insect-pest, as their interaction was significant. It indicated that the incidence of the pests varied with the varying spacing and fertilizer levels.

Incidence of serpentine leaf miner

The population of leaf miner was found fluctuating in all the observed nine weeks and at all the three levels of spacing being significantly different from each other. The wider spacing of 45 × 60 cm (P_3) resulted in a minimum mean population (2.12 larvae per five leaves) of leaf miner as compared to moderate spacing of 45×45 cm (P_2) with 2.52 larvae per five leaves and a closer spacing level of 45 × 30 cm (P_1) with a maximum of 3.16 larvae per five leaves. It is revealed that at a wider spacing level the population of leaf miner was significantly lower than the narrower spacing (Table 2).Studies (El- Ghanam, 2016)on pea suggested that at closer spacing (10 cm) incidence of leaf miner was more, with 30.7 larvae per fifteen leaves whereas, at spacing 30 cm, the larval count was 5.16 per fifteen leaves.

Lowest mean population (2.30 larvae per five leaves) was observed at higher fertigation level of 125% RDF (F_2) (78.12: 125: 93.75 NPK kg/ha) as compared to other two fertiliser levels of 100% RDF (F_1) (62.5: 100: 75 NPK kg/ha) and 75%RDF (F_3) (46.87:75:56.25 NPK kg/ha), both with 2.74 larvae per five leaves. It suggested that at higher fertigation level the population was significantly minimum than other levels. Facknath and Lalljee (2005) reported on the potato that, although nitrogen showed a positive effect on leaf miner population, potassium had a negative effect on it, which supports the present

Table 2. Effect of crop geometry and fertilizer dosages on the population of leaf miner

Treatment	Mean population per five leaves (weeks after fertigation)										Mean
	Pre-count	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th Week	9th Week	
Spacing level											
P_1	2.71(1.79)^{a}	3.44(1.98)^{a}	3.57(2.01)^{a}	3.80(2.07)^{a}	3.05(1.88)^{a}	3.03(1.87)^{a}	2.83(1.83)^{a}	2.81(1.81)^{a}	2.96(1.85)^{a}	2.95(1.85)^{a}	3.16
P_2	2.10(1.61)^{b}	2.42(1.71)^{b}	2.81(1.82)^{b}	2.96(1.86)^{b}	2.38(1.70)^{b}	2.42(1.70)^{b}	2.30(1.67)^{b}	2.28(1.66)^{b}	2.41(1.70)^{b}	2.58(1.75)^{b}	2.51
P_3	1.51(1.41)^{c}	2.03(1.59)^{c}	2.28(1.66)^{c}	2.28(1.66)^{c}	2.03(1.59)^{c}	2.00(1.58)^{c}	1.94(1.56)^{c}	1.90(1.54)^{c}	2.27(1.66)^{b}	2.38(1.69)^{b}	2.12
SEm ±	0.02	0.03	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02	
CD (P=0.05)	0.07	0.1	0.07	0.10	0.06	0.05	0.05	0.06	0.07	0.06	
Remark	S	S	S	S	S	S	S	S	S	S	
Fertilizer level											
F_1	2.15(1.62)	2.73(1.79)	2.94(1.84)^{ab}	3.08(1.88)^{ab}	2.70(1.78)^{a}	2.67(1.78)^{a}	2.57(1.75)^{a}	2.51(1.73)^{a}	2.71(1.78)^{a}	2.77(1.80)^{b}	2.74
F_2	2.05(1.60)	2.74(1.79)	3.04(1.88)^{a}	3.21(1.92)^{a}	2.08(1.60)^{b}	1.94(1.57)^{b}	1.87(1.53)^{b}	1.78(1.51)^{b}	2.00(1.58)^{b}	2.09(1.61)^{c}	2.30
F_3	2.18(1.60)	2.42(1.70)	2.68(1.78)^{b}	2.74(1.79)^{b}	2.69(1.78)^{a}	2.81(1.81)^{a}	2.68(1.78)^{a}	2.67(1.78)^{a}	2.94(1.85)^{a}	3.05(1.88)^{a}	2.74
SEm ±	0.02	0.03	0.02	0.03	0.02	0.01	0.02	0.02	0.02	0.02	
CD (P=0.05)			0.07	0.10	0.06	0.05	0.05	0.06	0.07	0.06	
Remark	NS	NS	S	S	S	S	S	S	S	S	
Interaction level											
T_{1-} P_1 F_1	2.71(1.79)	3.50(2.00)	3.53(2.03)	4.08(2.14)	3.58(2.02)^{a}	3.40(1.97)^{a}	3.28(1.94)^{a}	3.20(1.92)	3.32(1.95)	3.25(1.93)	3.30
T_2-P_1 F_2	2.58(1.75)	3.6(2.04)	3.92(2.10)	3.83(2.08)	2.42(1.71)^{def}	2.13(1.62)^{ef}	2.11(1.62)^{efg}	2.06(1.60)	2.07(1.60)	2.11(1.61)	2.69
T_{3-} P_1 F_3	2.83(1.82)	3.1791.91)	3.17(1.91)	3.50(2.00)	3.17(1.91)^{a}	3.58(2.02)^{a}	3.25(1.94)^{a}	3.16(1.91)	3.50(2.00)	3.50(2.00)	3.47
T_{4-} P_2 F_1	2.05(1.60)	2.52(1.74)	3.02(1.87)	3.02(1.87)	2.51(1.74)^{cde}	2.51(1.74)^{c}	2.35(1.69)^{cdef}	2.30(1.67)	2.50(1.73)	2.66(1.77)	2.60
T_{5-} P_2 F_2	2.08(1.63)	2.57(1.75)	2.74(1.80)	3.27(1.94)	2.08(1.61)^{fgh}	2.10(1.61)^{f}	2.00(1.58)^{g}	1.92(1.55)	2.00(1.58)	2.08(1.60)	2.31
T_{6-} P_2 F_3	2.17(1.47)	2.17(1.63)	2.68(1.78)	2.58(1.75)	2.57(1.75)^{bcde}	2.63(1.77)^{bc}	2.56(1.75)^{bc}	2.62(1.76)	2.73(1.800	3.00(1.87)	2.61
$T_{7-}$$P_3$ F_1	1.68(1.41)	2.17(1.63)	2.17(1.63)	2.17(1.63)	2.00(1.58)^{gh}	2.08(1.61)^{f}	2.10(1.61)^{fg}	2.08(1.60)	2.32(1.68)	2.40(1.70)	2.16
$T_{8-}$$P_3$ F_2	1.50(1.36)	2.00(1.58)	2.48(1.73)	2.52(1.74)	1.75(1.50)^{h}	1.67(1.47)^{g}	1.50(1.41)^{h}	1.38(1.37)	1.92(1.55)	2.08(1.60)	1.92
T_{9-} P_3 F_3	1.35(1.63)	1.93(1.55)	2.18(1.64)	2.15(1.63)	2.35(1.69)^{efg}	2.22(1.65)^{def}	2.23(1.65)^{defg}	2.23(1.65)	2.58(1.75)	2.67(1.78)	2.28
control	2.17	2.47(1.71)	2.70(1.79)	3.25(1.93)	3.78(2.07)	4.17(2.15)	4.23(2.18)	4.23(2.17)	4.63(2.26)	4.82(2.30)	3.80
SEm ±	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.04	0.04	
CD (P=0.05)					0.11	0.08	0.09				
Remark	NS	NS	NS	NS	S	S	S	NS	NS	NS	

S- Significant; NS- Non significant; *precount – no fertiliser was applied; Values in parentheses square root transformation= √(x+0.5); Means followed by same letter in a column do not differ significantly (DMRT, p = 0.05) ; P_1 :45 X 30 cm, P2 : 45 cm x 45 cm, P3 : 45 cm x 60 cm; F1: 100% RDF, F2: 125% RDF, F3: 75% RDF; P_1 F_1 : 45 cm x 30 cm + 100% RDF , P_1 F_2: 45 cm x 30 cm + 125% RDF P_1 F_3: 45 cm x 30 cm + 75% RDF, P_2 F_1 : 45 cm x 45 cm + 100% RDF, P_2 F_2: 45 cm x 45 cm + 125% RDF, P_2 F_3 : 45 cm x 45 cm + 75% RDF, P_3 F_1: 45 cm x 60 cm + 100% RDF, P_3 F_2: 45 cm x 60 cm + 125% RDF, P_3 F_3: 45 cm x 60 cm + 75% RDF

Table 3. Effect of crop geometry and fertilizer dosages on the population of spider mite

Treatment	Mean population per three leaves (weeks after fertigation)									
	Pre-count	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	Mean
P_1	3.75(2.06)^{a}	4.35(2.19)^{a}	4.57(2.24)^{a}	3.61(2.02)^{a}	3.57(2.01)^{a}	3.04(1.87)^{a}	4.33(2.19)^{a}	4.24(2.17)^{a}	4.20(2.16)^{a}	3.92
P_2	2.66(1.77)^{b}	3.08(1.89)^{b}	3.55(2.01)^{b}	3.14(1.91)^{b}	2.98(1.86)^{b}	2.42(1.71)^{b}	3.56(2.01)^{b}	3.33(1.95)^{b}	4.00(2.11)^{a}	3.22
P_3	1.65(1.46)^{c}	2.22(1.64)^{c}	2.57(1.74)^{c}	2.53(1.73)^{c}	2.42(1.70)^{c}	2.00(1.58)^{c}	2.57(1.74)^{c}	2.71(1.78)^{c}	2.63(1.76)^{b}	2.68
SEm ±	0.08	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	
CD (P=0.05)	0.23	0.16	0.07	0.10	0.07	0.05	0.07	0.05	0.06	
Remark	S	S	S	S	S	S	S	S	S	
F_1	2.45(1.71)	3.22(1.92)^{b}	3.49(1.99)^{b}	3.13(1.89)^{b}	2.92(1.84)^{b}	2.67(1.77)^{b}	3.42(1.97)^{b}	3.54(2.01)^{b}	3.69(2.04)^{b}	3.28
F_2	2.94(1.82)	3.81(2.05)^{a}	4.25(2.16)^{a}	2.62(1.77)^{c}	2.35(1.68)^{c}	1.97(1.57)^{c}	2.92(1.84)^{c}	2.56(1.74)^{c}	2.86(1.82)^{c}	3.16
F_3	2.67(1.76)	2.62(1.75)^{c}	2.94(1.84)^{c}	3.58(2.00)^{a}	3.69(2.04)^{a}	2.81(1.81)^{a}	4.12(2.14)^{a}	4.17(2.15)^{a}	4.29(2.18)^{a}	3.38
SEm ±	0.08	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	
CD (P=0.05)		0.12	0.07	0.10	0.07	0.05	0.07	0.05	0.06	
Remark	NS	S	S	S	S	S	S	S	S	
T_{1}- P_1 F_1	3.25(1.93)	4.25(2.18)^{b}	4.42(2.22)^{bc}	3.67(2.04)	3.50(2.00)	3.40(1.97)^{a}	4.23(2.20)^{bc}	4.23(2.27)^{b}	4.00(2.12)	3.96
T_2-P_1 F_2	4.50(2.23)	5.47(2.44)^{a}	5.78(2.51)^{a}	3.00(1.87)	2.78(1.81)	2.13(1.62)^{ef}	3.33(1.98)^{def}	3.17(1.91)^{ef}	3.50(2.00)	3.64
T_{3}- P_1 F_3	3.50(2.00)	3.33(1.96)^{def}	3.50(2.00)^{defg}	4.17(2.16)	4.42(2.22)	3.58(2.02)^{a}	5.23(2.40)^{a}	5.32(2.41)^{a}	5.17(2.38)	4.34
T_{4}- P_2 F_1	2.33(1.67)	3.00(1.87)^{efgh}	3.40(1.97)^{efg}	3.07(1.89)	2.92(1.85)	2.52(1.74)^{cd}	3.23(1.96)^{ef}	3.40(1.97)d^{e}	4.15(2.16)	3.21
T_{5}- P_2 F_2	2.82(1.81)	3.40(1.97)^{cdef}	3.92(2.10)^{cde}	2.85(1.83)	2.43(1.71)	2.10(1.61)^{f}	2.33(1.96)^{ef}	2.50(1.73)^{g}	3.17(1.91)	2.84
T_{6}- P_2 F_3	2.83(1.81)	2.83(1.81)^{fgh}	3.33(1.96)^{fg}	3.50(2.00)	3.58(2.02)	2.63(1.77)^{bc}	4.00(2.12)^{c}	4.08(2.14)^{c}	4.67(2.27)	3.57
T_{7}-P_3 F_1	1.77(1.50)	2.42(1.70)^{h}	2.67(1.77)^{h}	2.67(1.77)	2.33(1.68)	2.08(1.61)^{f}	2.92(1.75)^{g}	2.98(1.87)^{f}	2.92(1.85)	2.62
T_{8}-P_3 F_2	1.50(1.41)	2.57(1.75)^{gh}	3.05(1.88)^{gh}	2.00(1.58)	1.83(1.53)	1.67(1.47)^{g}	1.92(1.58)^{h}	2.00(1.58)^{h}	1.91(1.55)	2.12
T_{9}- P_3 F_3	1.69(1.47)	1.69(1.48)^{i}	2.00(1.58)^{i}	2.97(1.85)	3.08(1.89)	2.22(1.65)^{def}	3.05(1.90)^{f}	3.13(1.91)^{ef}	3.05(1.88)	2.68
control	3.00(1.87)	3.59(2.02)	3.92(2.10)	3.92(2.10)	4.58(2.25)	5.22(2.39)	7.15(2.69)	7.15(2.77)	7.17(2.77)	5.33
SEm ±	0.10	0.07	0.04	0.04	0.03	0.03	0.04	0.03	0.02	
CD (P=0.05)		0.20	0.13			0.09	0.12	0.09		
Remark	NS	S	S	NS	NS	S	S	S	NS	

S- Significant; NS- Non significant; *precount – No fertiliser was applied; Values in parentheses square root transformation= √(x+0.5); Means followed by same letter in a column do not differ significantly (DMRT, p = 0.05); P_1 :45 X 30 cm, P2 : 45 cm x 45 cm, P3 : 45 cm x 60 cm; F1: 100% RDF, F2: 125% RDF, F3: 75% RDF; P_1 F_1 : 45 cm x 30 cm + 100% RDF , P_1 F_2: 45 cm x 30 cm + 125% RDF P_1 F_3: 45 cm x 30 cm + 75% RDF, P_2 F_1 : 45 cm x 45 cm + 100% RDF, P_2 F_2: 45 cm x 45 cm + 125% RDF, P_2 F_3 : 45 cm x 45 cm + 75% RDF, P_3 F_1: 45 cm x 60 cm + 100% RDF, P_3 F_2: 45 cm x 60 cm + 125% RDF, P_3 F_3: 45 cm x 60 cm + 75% RDF (activity of spider mites started from second week of observation) investigation. According to another research (Marschner, 1995) a theory of nutrient□dilution phenomenon was explained, where an increase in one nutrient might increase the growth of the plant but lead to the dilution or decrease in other nutrient levels in the plant, which is in congruence with the present investigation that may be due to more phosphorus dose, uptake of nitrogen uptake might have been reduced causing lesser infestation by the miner.

The interaction results between the spacing of crop and fertilizer doses were found significant in governing the population, some weeks after fertigation (fifth, sixth, and seventh week). The interaction (T_8) between spacing level 45 × 60 cm (P_3) and fertilizer level 125% RDF (F_2) resulted in a minimum mean population of a leaf miner (1.92 larvae per five leaves) as compared to all other treatment combinations. The degree of population build-up was of the order T_3 (P_1 F_1) > T_1 (P_1 F_3) > T_2 (P_1 F_2) > T_6 (P_2 F_3) > T_4 (P_2 F_1) > T_5 (P_2 F_2) > T_9 (P_3 F_3) > T_7 (P_3 F_1) > T_8 (P_3 F_2). It can be interpreted from the above results that, wider spacing levels and increased fertilizer dosage lead to minimum population incidence. There are no previous reports on the effects of both the crop spacing and fertigation level on *L. trifolii* infestation on pole bean under the net house.

Incidence of spider mite

The lowest mean population (2.68 mites per three leaves) was found at a wider spacing of 45 × 60 cm (P_3) as compared to closer spacing 45 × 30 cm (P_1) (3.92 mites per three leaves) and followed by the moderate spacing of 45×45 cm (P_2) (3.22 mites per three leaves). This indicated that a wider spacing results in the lowest population of spider mites (Table 3).The population of sucking pests on cotton plants decreased with an increase in plant spacing (Momtaz *et al*., 2018) Chilli mites were significantly more in the lesser spacing of 60×30 cm (0.65 mites per leaf), while the number of mites recorded was significantly lower at a higher spacing of 90×60 cm (0.44 per leaf), under open field condition (Sujay and Giraddi, 2014).

Different fertigation levels also affected significantly the population of spider mites. The mean population of 3.16 mites per three leaves, was at the lowest in higher fertigation of 125% RDF as compared to 100% RDF with 3.28 mites per three leaves and 75% RDF with 3.38 mites per three leaves. The findings hence suggested that higher fertigation followed a population reduction. Bala *et al*. (2018) suggested that higher doses of potassium reduced the uptake of nitrogen, hence giving the plant resistance against the herbivores. More nitrogenous fertilizer led to the mortality of the spider mites, as observed on beans in field conditions (Ghallab *et al*., 2012 and Najafabadi *et al*., 2011). Earlier reports (Busch and Phelan, 1999) on soybean that application of phosphorus alone showed a significant decline in mite's population but combination (NPK) had no significant effect on them.

The interaction between the crop spacing and fertilizer doses at different treatment levels was found significant in influencing the population of spider mites at weeks after fertigation (first, second, fifth, sixth, and seventh week). From the overall mean population growth over the weeks observed, the lowest population (2.12 mites per three leaves) was observed at T_8: 45 × 60 cm + 125% RDF (P_3 F_2) as compared to all other treatment combinations. The degree of population escalation at different treatments is in the order: T_3 (P_1 F_3) > T_1 (P_1 F_1) > T_2 (P_1 F_2) > T_6 (P_2 F_3) > T_4 (P_2 F_1) > T_5 (P_2 F_2) > T_9 (P_3 F_3) > T_7 (P_3 F_1) > T_8 (P_3 F_2). It is interpreted from the above results that a wider spacing level and increased fertilizer dosage (more than RDF) led to a minimal population development in spider mites. The sucking pest population decreased when only nitrogen fertilizer was nourished in a minimum dose with wider plant spacing in the cotton ecosystem (Patel and Saha, 2015).

Incidence of leafhopper

Wider spacing of 45 × 60 cm (P_3) ensured in the lowest mean population (0.33 leafhopper per three leaves) followed by the moderate spacing of 45×45 cm (P_2) (0.47 leafhopper per three leaves) and then closer spacing of 45 × 30 cm (P_1) (0.60 leafhoppers per three leaves), recording highest population (Table 4).The findings indicate that the population was least at wider crop spacing and higher recommended dose (potassium and phosphorus is more than nitrogen in RDF). The leafhopper (*Amrasca bigutulla bigutulla*) population was significantly highest in wider spacing between the Bt cotton plants, as studied earlier by Kalaichelvi, 2008; Patel and Shah, 2015 and Shweta *et al*., 2009.

Different levels of fertigation also had a significant effect. The overall mean population per three leaves was the lowest of 0.41 leafhopper at higher fertigation of 125% RDFas compared to 100% RDF and 75% RDF application. The negative effect of potassium was noticed on leafhoppers infesting potato (Parihar and Upadhyaya, 2001). Jakhar *et al*. 2017, reported on Indian bean (Lablab bean) that nitrogen affects positively to the sucking pests population whereas effect was negative due to phosphorus application.

The interaction between the crop spacing and fertilizer doses was found significant at fifth and sixth weeks after fertigation. As compared to all other treatment

Table 4. Effect of crop geometry and fertilizer dosages on the population of leafhoppers

Treatment	Mean population per five leaves (weeks after fertigation)								
	Pre-count	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	Mean
Spacing level									
P_1	0.41(0.95)^{a}	0.75(1.12)^{a}	0.82(1.15)^{a}	0.69(1.09)^{a}	0.40(0.94)^{a}	0.39(0.94)^{a}	0.66(1.07)^{a}	0.67(1.08)^{a}	0.60
P_2	0.28(0.88)^{b}	0.60(1.05)^{b}	0.63(1.06)^{b}	0.53(1.01)^{b}	0.31(0.90)^{b}	0.28(0.88)^{b}	0.44(0.97)^{b}	0.48(1.00)^{b}	0.47
P_3	0.19(0.83)^{c}	0.42(0.96)^{c}	0.50(1.00)^{c}	0.35(0.92)^{c}	0.21(0.84)^{c}	0.20(0.83)^{c}	0.29(0.90)^{c}	0.33(0.91)^{c}	0.33
SEm ±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
CD (P=0.05)	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.02	
Remark	S	S	S	S	S	S	S	S	
Fertilizer level									
F_1	0.28(0.88)	0.62(1.06)^{b}	0.61(1.05)^{b}	0.53(1.01)^{b}	0.32(0.90)^{b}	0.31(0.90)^{b}	0.50(1.00)^{b}	0.53(1.01)^{b}	0.46
F_2	0.32(0.90)	0.70(1.10)^{a}	0.84(1.16)a	0.41(0.95)^{c}	0.20(0.84)^{c}	0.15(0.81)^{c}	0.31(0.90)^{c}	0.35(0.92)^{c}	0.41
F_3	0.29(0.89)	0.45(0.97)^{c}	0.50(1.00)^{c}	0.64(1.07)^{a}	0.39(0.94)^{a}	0.41(0.95)^{a}	0.59(1.04)^{a}	0.61(1.05)^{a}	0.48
SEm ±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
CD (P=0.05)	0.03	0.02	0.02	0.02	0.03	0.03	0.02	0.02	
Remark	NS	S	S	S	S	S	S	S	
Interaction level									
$T_{1-}P_1F_1$	0.41(0.95)	0.77(1.12)	0.81(1.14)	0.67(1.08)	0.38(1.08)	0.38(0.94)^{cd}	0.68(1.08)^{b}	0.72(1.11)	0.60
T_2-P_1F_2	0.45(0.97)	0.87(1.17)	1.07(1.25)	0.55(1.02)	0.30(1.02)	0.22(0.85)^{fg}	0.41(0.94)^{de}	0.48(1.00)	0.54
$T_{3-}P_1F_3$	0.37(0.93)	0.63(1.06)	0.60(1.05)	0.87(1.17)	0.52(1.17)	0.58(1.04)^{a}	0.88(1.18)^{a}	0.82(1.15)	0.66
$T_{4-}P_2F_1$	0.25(0.86)	0.63(1.06)	0.58(1.04)	0.53(1.02)	0.32(1.01)	0.27(0.89)^{def}	0.50(1.00)^{c}	0.53(1.01)	0.45
$T_{5-}P_2F_2$	0.30(0.89)	0.72(1.10)	0.82(1.14)	0.47(0.95)	0.20(0.95)	0.18(0.82)^{g}	0.33(0.91)^{ef}	0.33(0.91)	0.42
$T_{6-}P_2F_3$	0.30(0.89)	0.45(0.97)	0.50(1.00)	0.65(1.07)	0.40(1.07)	0.40(0.95)^{bcd}	0.50(1.00)^{c}	0.58(1.04)	0.47
$T_{7-}P_3F_1$	0.16(0.81)	0.47(0.98)	0.45(0.97)	0.38(0.94)	0.26(0.93)	0.30(0.89)^{de}	0.30(0.89)^{f}	0.33(0.91)	0.37
$T_{8-}P_3F_2$	0.20(0.83)	0.53(1.02)	0.65(1.07)	0.27(0.87)	0.12(0.87)	0.07(0.75)^{h}	0.20(0.84)^{g}	0.23(0.85)	0.33
$T_{9-}P_3F_3$	0.20(0.83)	0.27(0.87)	0.40(0.95)	0.42(0.96)	0.27(0.95)	0.24(0.86)^{efg}	0.38(0.94)^{de}	0.42(0.96)	0.40
control	0.36(0.93)	0.75(1.11)	1.00(1.22)	1.00(1.22)	1.20(1.22)	0.80(1.14)	0.80(1.14)	1.00(1.22)	0.93
SEm ±	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	
CD (P=0.05)						0.06	0.03		
Remark	NS	NS	NS	NS	NS	S	S	NS	

S- Significant; NS- Non significant; *precount – No fertiliser was applied; Values in parentheses square root transformation= $\sqrt{(x+0.5)}$; Means followed by same letter in a column do not differ significantly (DMRT, p = 0.05); P_1 :45 X 30 cm, P2 : 45 cm x 45 cm, P3 : 45 cm x 60 cm; F1: 100% RDF, F2: 125% RDF, F3: 75% RDF; P_1F_1 : 45 cm x 30 cm + 100% RDF , P_1F_2: 45 cm x 30 cm + 125 per cent RDF P_1F_3: 45 cm x 30 cm + 75 per cent RDF, P_2F_1 : 45 cm x 45 cm + 100 per cent RDF, P_2F_2: 45 cm x 45 cm + 125 per cent RDF, P_2F_3 : 45 cm x 45 cm + 75 per cent RDF, P_3F_1: 45 cm x 60 cm + 100 per cent RDF, P_3F_2: 45 cm x 60 cm + 125 per cent RDF, P_3F_3: 45 cm x 60 cm + 75 per cent RDF (Activity of leafhopper started from third week of observation)

Table 5. Effect of crop geometry and fertilizer dosages on the population of tobacco caterpillar

Treatment	Pre-count	Mean population per meter length (weeks after fertigation)									
		1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th Week	9th Week	Mean
Spacing level											
P_1	0.17(0.82)^{a}	0.41(0.95)^{a}	0.39(0.94)^{a}	0.39(0.95)^{a}	0.42(0.96)^{a}	0.38(0.94)^{a}	0.39(0.94)^{a}	0.40(0.94)^{a}	0.40(0.95)^{a}	0.33(0.91)^{a}	0.39
P_2	0.15(0.81)^{a}	0.35(0.93)^{b}	0.27(0.88)^{b}	0.24(0.86)^{b}	0.27(0.88)^{b}	0.26(0.87)^{b}	0.27(0.88)^{b}	0.31(0.90)^{b}	0.26(0.87)^{b}	0.26(0.87)^{b}	0.28
P_3	0.12(0.79)^{b}	0.23(0.85)^{c}	0.2(0.83)^{c}	0.19(0.83)^{c}	0.21(0.84)^{c}	0.21(0.84)^{c}	0.25(0.86)^{c}	0.25(0.86)^{c}	0.23(0.85)^{b}	0.23(0.85)^{b}	0.22
SEm ±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
CD (P=0.05)	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	
Remark	S	S	S	S	S	S	S	S	S	S	
Fertilizer level											
F_1	0.15(0.81)	0.31(0.90)^{b}	0.27(0.87)^{b}	0.27(7.87)^{b}	0.29(0.87)^{b}	0.28(0.88)^{b}	0.39(0.94)^{a}	0.40(0.94)^{a}	0.40(0.95)^{a}	0.33(0.91)^{a}	0.39
F_2	0.15(0.81)	0.40(0.95)^{a}	0.42(0.96)^{a}	0.19(7.45)^{c}	0.22(0.85)^{b}	0.20(0.83)^{c}	0.27(0.88)^{b}	0.31(0.90)^{b}	0.26(0.87)^{b}	0.26(0.87)^{b}	0.28
F_3	0.15(0.81)	0.28(0.89)^{c}	0.17(0.83)^{c}	0.37(8.37)^{a}	0.39(0.94)^{a}	0.37(0.93)^{a}	0.25(0.86)^{c}	0.25(0.86)^{c}	0.23(0.85)^{b}	0.23(0.85)^{b}	0.22
SEm ±		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
CD (P=0.05)		0.01	0.02	0.2	0.02	0.02	0.02	0.03	0.02	0.02	
Remark	NS	S	S	S	S	S	S	S	S	S	
Interaction level											
T_{1}- P_1 F_1	0.17(0.82)	0.40(0.95)	0.37(0.93)	0.37(0.93)	0.40(0.95)^{b}	0.39(0.95)^{a}	0.39(0.95)^{bcd}	0.40(0.95)	0.38(0.94)	0.32(0.90)	0.38
T_2-P_1 F_2	0.18(0.82)	0.50(1.00)	0.55(1.02)	0.30(0.89)	0.33(0.91)^{cde}	0.28(0.88)^{def}	0.28(0.88)^{ef}	0.28(0.88)	0.32(0.90)	0.27(0.87)	0.35
T_{3}- P_1 F_3	0.18(0.82)	0.33(0.91)	0.25(0.87)	0.50(1.00)	0.52(1.01)^{a}	0.47(0.98)^{a}	0.50(1.00) a	0.52(1.01)	0.50(1.00)	0.40(0.95)	0.44
T_{4}- P_2 F_1	0.16(0.81)	0.32(0.90)	0.25(0.87)	0.25(0.87)	0.27(0.88)^{ef}	0.26(0.87)^{efg}	0.27(0.88)^{ef}	0.28(0.88)	0.27(0.87)	0.27(0.88)	0.27
T_{5}- P_2 F_2	0.15(0.81)	0.42(0.96)	0.40(0.95)	0.17(0.82)	0.22(0.85)^{fg}	0.22(0.85)^{fg}	0.22(0.85)^{f}	0.27(0.88)	0.20(0.84)	0.22(0.85)	0.26
T_{6}- P_2 F_3	0.15(0.81)	0.32(0.90)	0.17(0.82)	0.30(0.90)	0.32(0.90)^{de}	0.32(0.90)^{cde}	0.33(0.91)^{de}	0.37(0.93)	0.30(0.89)	0.30(0.89)	0.30
T_{7}-P_3 F_1	0.12(0.78)	0.20(0.84)	0.18(0.83)	0.18(0.83)	0.20(0.84)^{g}	0.20(0.84)^{g}	0.28(0.88)^{ef}	0.32(0.90)	0.23(0.86)	0.23(0.86)	0.22
T_{8}-P_3 F_2	0.12(0.78)	0.30(0.89)	0.30(0.89)	0.10(0.77)	0.10(0.77)^{h}	0.10(0.77)^{h}	0.10(0.77)^{g}	0.15(0.81)	0.13(0.80)	0.15(0.81)	0.16
T_{9}- P_3 F_3	0.12(0.78)	0.18(0.83)	0.12(0.79)	0.30(0.89)	0.33(0.91)^{cde}	0.33(0.91)^{bcd}	0.26(0.92)^{cde}	0.28(0.88)	0.32(0.90)	0.30(0.89)	0.26
Control	0.16(0.81)	0.29(0.89)	0.29(0.89)	0.40(0.95)	0.46(0.98)	0.50(1.00)	0.47(0.98)	0.32(0.95)	0.38(0.94)	0.36(0.93)	0.38
SEm ±	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02	
CD (P=0.05)					0.03	0.03	0.04				
Remark	NS	NS	NS	NS	S	S	S	NS	NS	NS	

S- Significant; NS- Non significant; *precount – No fertiliser was applied; Values in parentheses square root transformation= $\sqrt{(x+0.5)}$; Means followed by same letter in a column do not differ significantly (DMRT, p = 0.05); P_1 :45 X 30 cm, P2 : 45 cm x 45 cm, P3 : 45 cm x 60 cm; F1: 100% RDF, F2: 125% RDF, F3: 75% RDF; P_1 F_1 : 45 cm x 30 cm + 100% RDF , P_1 F_2: 45 cm x 30 cm + 125% RDF, P_1 F_3: 45 cm x 30 cm + 75% RDF, P_2 F_1 : 45 cm x 45 cm + 100% RDF, P_2 F_2: 45 cm x 45 cm + 125% RDF, P_2 F_3 : 45 cm x 45 cm + 75% RDF, P_3 F_1: 45 cm x 60 cm + 100% RDF, P_3 F_2: 45 cm x 60 cm + 125% RDF, P_3 F_3: 45 cm x 60 cm + 75% RDF combinations, the treatment T_8, characterized by wider spacing and higher fertilizer dosage- 45 × 60 cm + 125% RDF (P_3 F_2) with the mean population of 0.33 leafhopper per three leaves was found lowest from the overall mean of the observed weeks. The degree of population shoot up in different treatments was of the order: T_3 (P_1 F_3) > T_1 (P_1 F_1) > T_2 (P_1 F_2) > T_6 (P_2 F_3) > T_4 (P_2 F_1) > T_5 (P_2 F_2) > T_9 (P_3 F_3) > T_7 (P_3 F_1) > T_8 (P_3 F_2). It can be opined from the above results that wider spacing and increased fertilizer dosage (more than RDF) resulted in minimal population development.

Incidence of tobacco caterpillar

The population growth of *S. litura* was found fluctuating significantly in the cropping period concerning different spacing levels (Table 5). Wider spacing of 45×60 cm (P_3) ensured the lowest mean population (0.22 larvae per meter) followed by the moderate spacing of 45×45 cm (P_2) (0.28 larvae per meter) and then closer spacing of 45 × 30 cm (P_1) (0.39 larvae per meter). It was noted that the chili fruit borer (*Helicoverpa armigera*) larval population was found significantly least at wider spacing (Sujay *et al*., 2008).

Different levels of fertigation were also found significant in affecting the population of *S. litura*. The overall mean population per meter was lowest with 0.25 larvae, at higher fertigation of 125% RDF as compared to 100% RDF and 75%RDF application. It suggests that where the potassium content is more the incidence was less, which is supported by studies of Sudhakar *et al.,* 1998 and Bala *et al*., 2008) that there was an adverse effect of potassium fertilizers on the caterpillar pests. Reports (Thyagaraj and Chakravarthy, 1999) also stated that application of only nitrogen had a positive effect on borer infestation whereas the effect of nitrogen + potassium combination was negative.

The interaction between the crop spacing and fertilizer doses at different treatment levels was found significant (fourth, fifth, and sixth weeks after fertigation) in governing the population build-up of *S. litura*. As compared to all other treatment combinations, the treatment T_8: 45 × 60 cm + 125% RDF (P_3 F_2) with the mean population (0.16 larvae per meter) was found to harbor the lowest of the pest. The degree of population build-up at different treatments was of the order: T_3 (P_1 F_3) > T_1 (P_1 F_1) > T_2 (P_1 F_2) > T_6 (P_2 F_3)>T_4 (P_2 F_1) > T_5 (P_2 F_2) > T_9 (P_3 F_3) > T_7 (P_3 F_1) > T_8 (P_3 F_2). It can be interpreted that wider spacing and increased fertilizer dosage (more than RDF), made tobacco caterpillars the least active in terms of density of the crop.

The study about the effect of crop geometry and nutrient nourishment on the activity of insect pests indicated that when pole bean raised at a wider spacing of 45×60 cm with fertigation of 125% RDF (78.12:125:93.75 NPK kg per ha) resulted in the lowest population density whereas highest at the interaction of 45×30 cm spacing and 75% RDF (46.87:75:56.25 NPK kg per ha). This throws light on the fact that wider spacing levels with a higher dose of RDF lead to a decline in population and eventual damage caused by the insect pest. However, these conclusions are to be confirmed by another two to three season studies, both in net house and polyhouse conditions.

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