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N and K fertilizer application rate under drip-fertigation for greenhouse grown sweet pepper

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ABSTRACT

Drip fertigation is an effective way to apply water soluble fertilizer in a split doses to meet water and nutrient demands of sweet pepper (*Capsicum annuum* L.). The application rates of N and K through urea and muriate of potash (MOP) were evaluated for sweet pepper under naturally ventilated greenhouse during two consecutive seasons of 2010-11 and 2011-12. Eleven N and K fertilizer combinations, including nine combinations of urea and MOP, one commercially available ready mix dry liquid (water soluble) fertilizer with a ratio of 20:20:20 and a control, were applied through low head drip irrigation system weekly in 32 equal split doses. Uniform P (through surface) was applied in all the treatments. The two years average maximum yield of 62.2 t ha^{-1} was achieved at the fertilizer rate of 400 kg N ha^{-1} and 360 kg K ha^{-1}. This yield was significantly higher than the average yield of 56.1 t ha^{-1} recorded from the normal recommended dose of 320 kg N ha^{-1} and 360 kg K ha^{-1}and was at par with 400 kg N ha^{-1} and 450 kg K ha^{-1} (59.4 t ha^{-1}). The average yield obtain from the fertilizer rate of 400 kg N ha^{-1}and 360 kg K ha^{-1} was 11, 26 and 104% higher than the fertilizer application of normal dose, ready mix dry liquid fertilizer and the control, respectively. These results were obtained after enhancing the rate of application of N fertilizer by 25% while keeping the normal dose of application of K fertilizer.

Key words: Sweet pepper, greenhouse, drip-fertigation, chemical fertilizer.

INTRODUCTION

Drip irrigation system is a conservative and effective means of supplying water directly to the plant roots without much loss of water resulting in higher water productivity (Sripunitha *et al.*, 15; Khanna and Kumar, 8). The application of fertilizer to the field with irrigation water through drip is called fertigation (Shinde and Firake, 13). Fertigation offers precise control on fertilizer application and can be adjusted to the rate of plant nutrient uptake (Tiwari, 16). The suitable fertilizers, water soluble fertilizers, ready-to-mix water soluble fertilizers (dry liquid fertilizers) such as 20-20-20 are more being used by growers. However, they are generally more expensive compared to the urea and MOP (Christensen, 3). Development of acid based fertilizers offers some solution to these problems (Ryan and Saleh, 12), the adoption of conventional P fertilizer is involved with low cost comparatively.

Sweet pepper, an economically potential vegetable is generally grown at high altitude (>1000 ft.) but more recently its cultivation in North Indian plains is gaining popularity (Singh e*t al.*, 14). A greenhouse production system of sweet peppers differs greatly from the traditional field system where plants are grown with (fertigation) drip irrigation (Elio *et al.*, 4). The rate of application of N and K fertilizers for sweet pepper under greenhouse cultivation along with drip fertigation is not known. Hence, there is a need for determining the N and K fertilizer application rates through drip fertigation. Therefore, a field study was carried out to develop conventional N and K fertilizer schedule under drip-fertigation for greenhouse grown sweet pepper.

MATERIALS AND METHODS

The investigations were conducted jointly at Water Technology Centre with the collaboration of Centre for Protected Cultivation Technology at IARI, New Delhi. The sweet pepper (*Capsicum annum* L.) variety Indra conducted for two consecutive seasons September 2010 to May 2011 and September 2011 to May 2012 under naturally ventilated greenhouse was selected for the investigation. The experiment was carried out with 11 treatments (Table 1) replicated three times in a randomized block design. First, virus-free healthy seedlings of the sweet pepper were raised under the modern nursery greenhouse one month prior to the date of transplanting. The soilless media for the nursery was prepared with the mixture of cocopeat, perlite and vermiculite in 3:1:1 ratio, respectively. The seedlings were transplanted in the field with

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Table 1. Details of the fertilizer treatments.

Symbol	Treatment	Amount of N and K (kg ha^{-1})	Source of nutrients
T_1	75% N and 75% K	240 N and 270 K	Urea and MOP
T_2	75% N and 100% K	240 N and 360 K	Urea and MOP
T_3	75% N and 125% K	240 N and 450 K	Urea and MOP
T_4	100% N and 75% K	320 N and 270 K	Urea and MOP
T_5	100% N and 100% K	320 N and 360 K	Urea and MOP
T_6	100% N and 125% K	320 N and 450 K	Urea and MOP
T_7	125% N and 75% K	400 N and 270 K	Urea and MOP
T_8	125% N and 100% K	400 N and 360 K	Urea and MOP
T_9	125% N and 125% K	400 N and 450 K	Urea and MOP
T_{10}	0% N and 0% K	0 N and 0 K	Control
T_{11}	100% N and 100% K	320 N and 360 K	20:20:20 (Dry liquid fertilizer)

the spacing of 45 cm x 30 cm in each dripping point emitter with a rated discharge of one lph. The lateral line diameter of drip system was 12 mm. Greenhouse sweet pepper cultivars are indeterminate in nature, hence training pruning, and trellising were done as suggested (James, 7).

The irrigation water was applied to the experimental plots through drip twice a week. The irrigation requirement was estimated based on daily pan evaporation. Eleven N and K fertilizer combinations, including nine combinations of urea and MOP, one ready-to-mix dry liquid (water soluble) fertilizer with a ratio of 20:20:20 and a control (without N and K), were applied through low head drip irrigation weekly in 32 equal split doses. For fertigation, normal dose of N and K for sweet pepper was kept as 320 and 360 kg ha^{-1}, respectively under greenhouse conditions (Hasan, 5). The fruits were harvested at red colour stage, except for first two harvests of green fruits in order to boost the crop growth. The growth parameters such as plant height, dry mater content and leaf area index were recorded. The measurements of fruit quality attributes such as average number of fruits and average fruit diameter were also recorded.

RESULTS AND DISCUSSION

Plant growth pattern in terms of plant height throughout the cropping period in both the seasons was graphically shown in Figs. 1 and 2. The rate of increase in plant height was rapid at the early stages of the growth till the month of December in both the years and was poor during January and February. Average growth rates during the period of two months in January and February was 9 and 7 cm in 2010/11 and 2011/12, respectively. It could be due to the effect of low temperature during that period. Earlier, James (7) reported that the optimum temperature for vegetative growth in sweet peppers is between 21

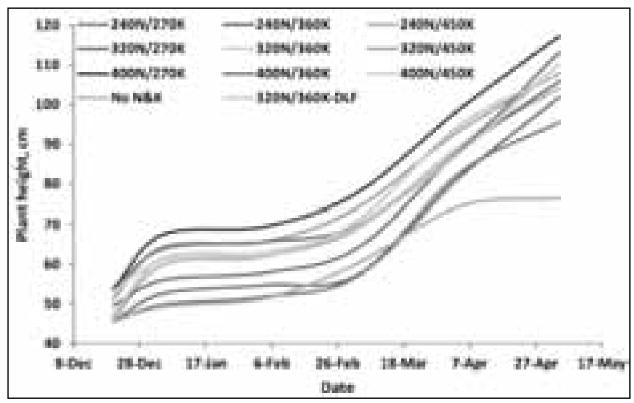

Fig. 1. Plant height during crop growth period in year 2010/11.

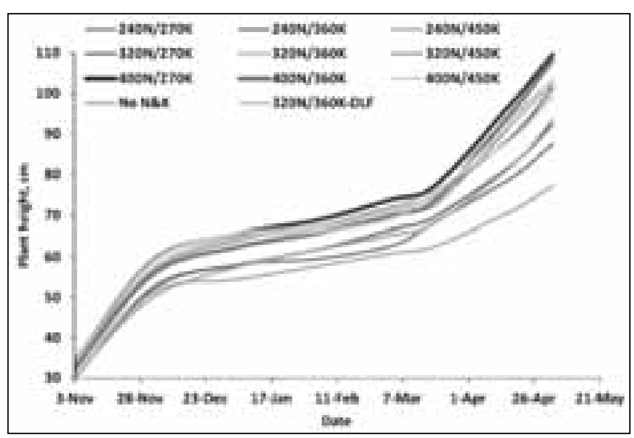

Fig. 2. Plant height during crop growth period in year 2011/12.

and 23°C. From the month of March onward, the plant height was in rapid increment as rise in temperature and penetration of solar radiation was in favour for better plant growth.

The average plant height at the 1st week of March was 68 cm in both the years. In the month of May, it reached at the average maximum height of 105 and 98 cm in year 2010/11 and 2011/12, respectively. The highest growth was observed in the treatment T_7 throughout the cropping period. From the month of March to May, the plant growth ranged from 78-117 and 74-110 cm in year 2010/11 and 2011/12, respectively. The nitrogen level with 360 and 400 kg ha^{-1} in the treatments of T_4, T_5, T_6, T_7, T_8, T_9 and T_{11} demonstrated better plant growth compared with the nitrogen level of 240 kg ha^{-1} covering the treatments of T_1, T_2 and T_3. Nitrogen fertilizer significantly affected plant height. Plant height was observed to be 7% lower in year 2011/12 compared with 2010/11. It was attributed to the variation in prevailing weather conditions.

The plant height at the end of cropping season is given in Table 2. It was found to be the highest (117 cm) at T_7 and was at par with all the treatments except T_1, T_2, T_3, T_{11} and control (T_{10}) in year 2010/11. In year 2011/12, the highest plant height was found to be 110 cm and it was significantly higher than the treatments of T_1, T_2, T_3, T_4, T_5, T_{11} and control. The plant height was observed to be increased with enhancing K level from 270 to 450 kg ha^{-1} only at the nitrogen level of 240 kg ha^{-1}. The result revealed that the increased nitrogen level enhanced only the plant growth. However, the balanced N and K level was required to boost the fruit yield. Aliyu (1) reported that excessive N supply stimulated excess vegetative growth, which was detrimental to reproductive growth and resulted in a decrease in fruit yield. Similar observation was reported by Haynes and Swift (6).

The maximum dry matter production of 102 and 84 g was observed in the year 2010/11 and 2011/12, respectively with the treatment T_7, whereas plant height was also found to be maximum. It was at par with the treatment of T_8 (87 g) in 2010/11. In 2011/12, the second highest dry matter production was observed to be 76 g in the treatment of T_8. It was at par with T_{11} (75 g) and T_5 (71 g) and was significantly higher than the all remaining treatments. The control produced the lowest dry matter ranged from 49 to 52 g. Influence of nutrients (N and K) in dry matter content was in line with the plant height.

The measurement of LAI was taken at the end of season in 2011/12 and presented in Table 2. LAI was found to be the highest (1.99 m^2m^{-2}) in the treatment of T_7 and was at par with T_8 (1.96 m^2m^{-2}) and T_5 (1.87 m^2m^{-2}) and significantly better than all the other 8 treatments. The lowest LAI (1.06 m^2m^{-2}) was observed in T_1. Leaf area index of treatment with ready mix dry liquid fertilizer was 1.16 m^2m^{-2} and it was similar to the treatments consisting of maximum fertilizer dose (T_9) and T_6. The differences of LAI due to the

Table 2. Plant height and dry matter content and leaf area index and number of fruits per plant in sweet pepper as affected by fertilizer treatments and drip irrigation.

Treatment	Plant height (cm)		Dry matter content (g)		Leaf area index (2011/12)	Av. No. of fruits/ plant	
	Year 2010/11	Year 2011/12	Year 2010/11	Year 2011/12		Year 2010/11	Year 2011/12
240N/270K	96	88	61	50	1.06	6.7	5.9
240N/360K	102	92	64	54	1.22	7.0	6.6
240N/450K	104	94	70	59	1.43	6.3	6.1
320N/270K	106	103	70	55	1.31	7.4	6.9
320N/360K	110	102	76	71	1.87	7.3	7.2
320N/450K	108	103	79	62	1.54	7.1	7.1
400N/270K	117	110	102	84	1.99	6.8	6.9
400N/360K	113	108	87	76	1.96	7.6	7.5
400N/450K	110	103	85	67	1.71	7.7	7.5
No N&K	76	77	52	49	1.11	3.9	4.8
320N/360K-DLF	108	99	80	75	1.62	6.6	6.5
LSD (P = 0.05)	11.3	6.0	16.4	5.6	0.18	0.9	1.0
CV%	6.4	3.58	12.8	5.14	6.77	7.9	8.6

treatments were tallied with the measurements of plant height and plant dry matter content. The results revealed that LAI was found to be increased when the N level was increased. It was accordance to the report of Lawlor *et al*. (7). They reported that in terms of growth, ample N increases the number of cells per leaf and can increase cell size; as a result leaf area is increased. Almost similar trend of LAI was observed with the plant height.

Based on season, it was found that the average number of fruits in the treatment of T_9 was 7.7 in 2010/11. It was the maximum and significantly higher than T_6 (6.7), T_{11} (6.6) and T_3 (6.3) and was at par with remaining 6 treatments. The treatment of T_5 produced 7.6 fruits per plant. In 2011/12, the maximum number of fruits of 7.5 was observed in the treatment T_8 and T_9. It was at par with the treatments except T_{11} (6.5), T_3 (6.1), T_1 (5.9) and control (4.8) (Table 2). Number of fruits was always high with the nitrogen level of 320 and 400 kg ha^{-1}compared with the treatments of 270 kg N ha^{-1}. Within the same level of N, there was no significant variation in number of fruits due to the various K levels. Based on the results, the N level should not be below 320 kg ha^{-1}. The applied rates of K did not influence number fruits per plant. Tumbare and Niikam (17) reported that nitrogen fertilizer increased fruit weight, yield and number of fruits in chilli peppers.

Data on average fruit diameter with different treatments for both seasons are given in Table 3. Observation indicated that the highest average fruit diameter of 74 mm was observed in the treatment of T_5. It was at par with T_6 (73 mm), T_7 (73 mm), T_8 (73 mm), T_9 (73 mm) and T_{11} (72 mm) and was significantly higher than T_1 (67 mm), T_2 (68 mm), T_3 (70 mm), T_4 (70 mm) and T_{10} (66 mm) in year 2010/11. In 2011/12, the highest average fruit diameter of 72 mm was observed to be in the treatment of T_7 and T_8. It was at par with T_5 (71 mm) and T_6 (70 mm) and was significantly higher than remaining 7 treatments. The lowest fruit diameter was found to be in control (63 mm). The guideline of sweet pepper grade in terms of fruit diameter from the University of Florida, USA was reported as: 1) above 80 mm – extra large; 2) 70-79 mm – large; 3) 60-69 mm – medium; 4) 50-59 mm – chopper (James, 7). According the above guideline, the sweet pepper fruits could be graded such as large diameter fruit in all the treatments except T_1, T_2 and control which are fold on the category of medium diameter in 2010/11. In 2011/12, the large diameter fruits were recorded in the treatment of T_5, T_6, T_7 and T_8. The remaining 7 treatments were produced medium fruit diameter. The result indicated that increasing N from 240 to 320 kg ha^{-1} enhanced the fruit diameter. However, further increment of N was not enhanced the fruit diameter significantly. Zhang *et al.* (19) reported that fruit quality indicated by fruit size improved with increases in N rate. The consistent large fruit size in terms of diameter would have partially contributed to the high marketable fruit yield. Bowen and Frey (2) reported that the large fruit size (diameter) was the main factor contributing to high fruit yield.

Table 3. Average fruit diameter in sweet pepper as affected by drip-fertigation treatments.

Treatment	Av. fruit dia. (mm)	
	2010/11	2011/12
240N/270K	67 ± 8	65 ± 7
240N/360K	68 ± 8	65 ± 8
240N/450K	70± 8	65 ± 7
320N/270K	70 ± 9	69 ± 8
320N/360K	74 ± 10	71 ± 7
320N/450K	73 ± 9	70 ± 8
400N/270K	73 ± 9	72 ± 7
400N/360K	73 ± 8	72 ± 9
400N/450K	73 ± 10	69 ± 6
No N&K	66 ± 7	63 ± 5
320N/360K-DLF	72 ± 8	69 ± 4
LSD (P = 0.05)	3	3
CV%	5.8	4.7

There were nine and seven harvests of sweet pepper fruit in year 2010/11 and 2011/12, respectively. The status of total fruit yield in both the years is graphically depicted in Fig. 5. The results revealed that the highest fruit yield was observed to be 65.9 and 58.5 t ha^{-1} during 2010/11 and 2011/12, respectively with the treatment of T_8. This yield was significantly higher than that of 59.8 and 52.4 t ha^{-1} in 2010/11 and 2011/12, respectively at the application of normal dose (T_5) and was at par with T_9 (63.6 and 55.2 t ha^{-1}) in both the years. The yield from the dry liquid (water soluble) fertilizer treatment was 52.6 and 45.9 t ha^{-1} in 2010/11 and 2011/12, respectively, which were significantly lower than that of other treatments. Among the urea and MOP combinations, the lowest yield was 50.6 and 38.8 t ha^{-1} with the treatment of T_1 in 2010/11 and 2011/12, respectively. It was at par with T_2 (53.8 and 42.6 t ha^{-1}) in both the years. The yield obtained from the treatment of T_6 was 58.0 and 48.1 t ha^{-1} in 2010/11 and 2011/12, respectively. It was at par with T_7 (58.5 and 48.2 t ha^{-1}) and significantly lower than that of normal dose in both the years. Lower yields were observed in the treatments of reduced and imbalanced N and K fertilizer combinations.

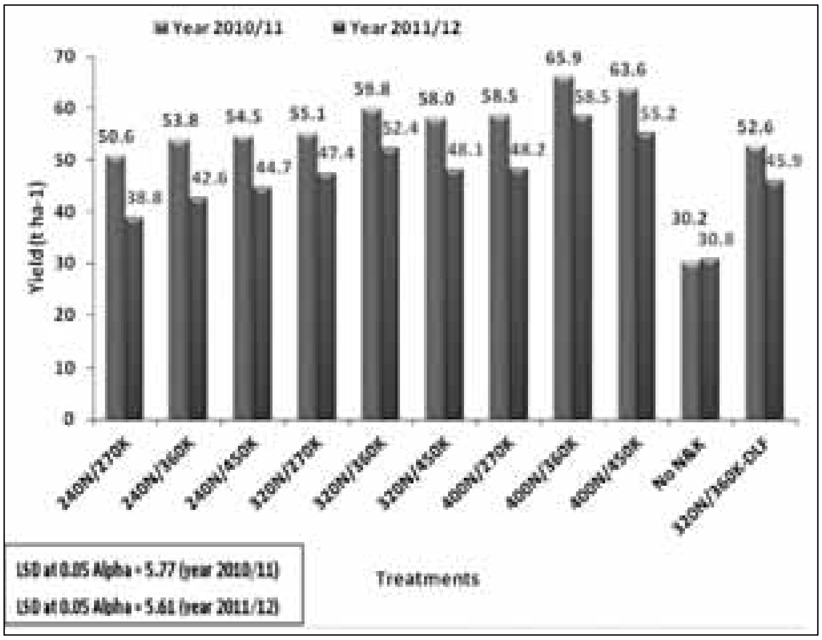

Fig. 3. Total yield of sweet pepper as affected by drip-fertigation treatments.

Increasing the nitrogen level by 25% of the recommended dose (320 kg ha^{-1}) promoted the yield level significantly. However, additional amount of potassium lead to the reduction in yield. It may be due to the antagonism effect between NH_4^+ and K^+ in which the plant uptake of these nutrients are controlled. Beneficial effect of NH_4^+-N on sweet pepper yield was significantly higher at lower dose of K than the higher dose (Xu *et al.*, 18). High K uptake, particularly in the presence of high N levels, has been reported (Olsen *et al.*, 10). Over application of N and K does not lead to further yield increments. Optimum N: K ratios are in favour of healthy plant growth and development whereas imbalance of N and K supply results in maladjustment of plant growth (Wells and Wood, 19). Qawasmi *et al*. (11) reported that increasing the rates of nitrogen applied in pepper increased the uptake of nitrogen by the plants and also stimulated the uptake of potassium and phosphorus through the synergistic effect.

Normal application of nitrogen for sweet peppers in greenhouse condition has been 320 kg ha^{-1}, which may not fulfill the development of yield potential under low head drip fertigation practice fixed into the naturally ventilated greenhouse. The nitrogen rate increased from 320 to 400 kg ha^{-1} with the normal dose of 360 kg ha^{-1} potassium enhanced the average yield from 56.1 to 62.2 t ha^{-1}. This average yield was 11, 26 and 104% higher than the fertilizer application of normal dose, dry liquid fertilizer and the control, respectively. However, it was also observed that an additional amount of potassium from 360 to 450 kg ha^{-1} with the N level of 400 kg ha^{-1} did not improved yield. However, the growth attributes indicated by plant height, dry matter content and LAI were superior with increase in N rate from 240 to 320 t ha^{-1}. As far as yield is concerned, the best results were obtained after enhancing the N fertilizer by 25% while keeping the normal dose of K fertilizer.

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