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Performance of Cabbage (*Brassica oleracea L. var. capitata*) in Relation to Fertigation using Variable Rates and Sources of Fertilizers

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A B S T R A C T

A field experiment was conducted to study the effect of fertigation on the performance of Cabbage variety Unnati at ICAR-Indian Institute of Horticultural Research, Bengaluru during *rabi* of 2013 and 2014. The experiment was laid out in Randomized Block Design with three replications and consisted of total ten treatments, which included different doses, sources of fertilizers and its frequency of application. The pooled analysis of two years data revealed that the application of fertilizer dose (150:100:125 kg NPK ha^{-1}) through fertigation using water soluble fertilizers on weekly interval resulted in higher values for plant height (29.56 cm), leaves per plant (25.67) and leaf weight per plant (599.30 gm) at 60 days after transplanting, which remained on par with the same dose and source applied at bi-weekly interval. Similarly, these two treatments recorded higher values for head weight (454.0 and 423.6 g), stem weight (102.3 and 94.0 g) and root weight (66.67 and 45.67 g) at harvest. All the fertigation treatments recorded higher yields over the conventional soil application of fertilizers to the tune of 6.5 – 60.3 per cent. Among the fertigation treatments, application of 100 per cent recommended dose using water soluble fertilizers at weekly interval resulted in significantly higher yield (60.86 t ha^{-1}) than all the other treatments tested except the treatment where the bi-weekly application of same dose of fertilizer through the same sources (58.82 t ha^{-1}) was done.

Introduction

Cabbage is one of the most popular vegetables grown in India. It is grown in 3.98 lakh hectares with a production of 90.37 lakh tonnes and a productivity of 22.70 tonnes per hectare (NHB, 2018). The major cabbage producing states are West Bengal, Odisha, Madhya Pradesh, Bihar, Assam, Gujarat and Uttar Pradesh. Cabbage is used as salad, boiled vegetable and dehydrated vegetable as well as in cooked curries and pickles. Cabbage is rich in minerals and vitamins A, B_1, B_2 and C (Hanif *et al.*, 2006).

Land, water and fertilizers are the important inputs for agricultural production systems and special attention is required for economic and efficient use of these limited and costly resources. About two thirds of the increase in production of food and fibre needed to satiate the increase in demand of the increasing

population has been attributed to irrigation. Drip irrigation is the most efficient system of irrigation in terms of economising the use of water by wetting the root zone of the crop (Sezen *et al.,* 2006). Vegetable production can be made more economical and efficient by adoption of micro irrigation methods which increases the crop yield to the tune of 25-30 per cent with 50 to 60 per cent saving of irrigation water over the conventional irrigation system (Yadav *et al*., 1993).

Fertigation is an eco-friendly and sustainable method of dispensing nutrients to the crop near the active root zone that increases crop productivity, quality and resource use efficiency. It is the most effective way to supply water and nutrients to the plant which not only saves water but also increases yield of fruits and vegetable (Spehia *et al.,* 2010). Studies have indicated that the fertilizer should be applied regularly and timely in small amounts for better plant growth and yield (Neeraja *et al.,* 1999). The cabbage crop responded well to N and K fertigation compared to soil application of recommended dose of fertilizers (Vasu and Reddy, 2013). Scientific information on fertigation especially on *Rabi* grown cabbage is very less, hence the present study was undertaken to determine the effect of fertigation of recommended dose of fertilizers and sources through drip irrigation for its commercial production.

Materials and Methods

The experiment was conducted at ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bengaluru, Karnataka, India during *rabi* of 2013 and 2014. The institute is situated at $13^0 7^{'}$ N latitude, $72^0 29^{'}$ E longitude and an elevation of 890 meters above mean sea level. The experimental soil was well drained sandy loam (pH 6.60 and electrical conductivity 0.25 dSm^{-1}) characterized by medium organic carbon (0.63%), low available N (169 kg ha^{-1}), high available P (78 kg ha^{-1}) and medium available K (260 kg ha^{-1}). The soil has available water holding capacity of 130 mm in one meter soil depth. The experiment was laid out in Randomized Block Design with ten treatments and three replications. Prior to planting, a uniform amount of farm yard manure @ 25 tonnes $hectare^{-1}$ was applied as basal application to all the treatments as common practice. The treatment details and quantity of different fertilizers applied have been given in Table 1 and 2. Urea, Polyfeed (19:19:19), Sulphate of potash and Muriate of potash were used as water soluble fertilizers for treatments T_3 to T_{10}, while urea, single super phosphate and muriate of potash were used as common fertilizers for treatments T_1 and T_2. The entire dose of P and half of N and K were applied as basal and remaining half of N and K was side dressed to soil at in equal splits 30 and 60 days after transplanting in T_1. The 30 days old seedlings of cabbage cultivar "Unnati" were transplanted at 80-40 x 30 cm plant to plant spacing, under paired row system during the first week of November during both the years. Drip irrigation was given depending on the rate of evaporation and amount of effective rainfall received. It worked out to be 310 mm and 280 mm of supplemental irrigation water for first and second year of cropping season after making necessary adjustment for the effective rainfall received. The fertigation treatments started after two weeks of planting and fertilizers were applied through drip system at weekly and bi-weekly interval. The treatments were imposed dissolving desired amounts of fertilizers and applied via venturi system through drip irrigation to the field. A total of 13 and 26 numbers of fertigations were given for weekly and bi-weekly interval, which was continued up to 15 days before completion of crop growth period. Five plants per replication in each of the treatments were selected randomly for recording yield

parameters. Recommended package of practices including agronomic and plant protection measures were adopted to raise the crop (Prabhakar *et al.,* 2010). The experimental data were statistically analysed (Gomez and Gomez, 1983) and compared using critical difference at five per cent probability level.

Results and Discussion

The data pertaining to plant growth, yield and yield attributing characters are presented in Table 3. The plants were taller (24.74 to 29.56 cm) and the values for plant spread where higher (32.26 to 38.33 cm), when the water soluble fertilizers applied through drip irrigation in split doses compared to soil application of fertilizers (23.59 and 30.65 cm) at 60 days after transplanting. Application of 100 per cent recommended dose of fertilizers through fertigation at weekly interval (T_3) recorded significantly taller plants (29.56 cm) than most of the treatments except T_4 (29.23 cm), T_7 (29.34 cm) and T_8 (28.80 cm).The significantly shortest plants were observed with soil application of common fertilizers (23.59 cm). Similarly, T_3 also recorded significantly higher plant spread of 38.33 cm, which remained on par with T_7 *i.e* application of same amount of water soluble fertilizers through fertigation on bi-weekly basis (37.47 cm). Increased plant height and spread with the application of 100 % fertilizer dose (150:100:125 kg NPK ha^{-1}) in 13 equal splits at 7 days intervals given at different stages might be due to availability of sufficient quantity of major nutrients, which subsequently resulted in higher values for plant height and spread. Other than this, higher frequency of irrigation and increased availability of soil moisture under drip irrigation coupled with fertigation might have led to effective absorption and utilization of these nutrients and better proliferation of roots resulting in better plant height and spread. The results are in conformity with Rakh (1992), Sanchita *et al.,* (2004), Singh *et al.,* (2006), Shinde *et al.,* (2006) and Tanpure *et al.,* (2007).

The pooled data analysis revealed that T_3 (application of 100 % NPK fertigation through water soluble fertilizers at weekly interval) recorded significantly higher number of leaves per plant (25.67) than T_1, T_2 and T_{10}. The lowest number of leaves per plant observed with T_1 (17.67). Kapoor *et al.,* (2014) and Yanglem and Tumbare (2015) also recorded higher number of leaves at higher levels of fertigation treatments than soil application of fertilizer with drip irrigation in cauliflower. Nitrogen is an important constituent of chlorophyll and proteins which is vital for vegetative growth. Phosphorus and potassium play a key role in physiological processes *viz*., photosynthesis, respiration, energy storage, cell division and cell enlargement (Sharma, 2016). Increase in number of leaves per plant might be attributed to balanced fertilization. Similar results have been reported by Sharma and Sharma (2010), Kumar *et al.,* (2013) and Shree *et al.,* (2014) in cauliflower.

The same treatment *i.e*. T_3 recorded significantly higher values for leaves weight per plant (599.3 g) than T_1 (360.0g), T_2 (395.0g) and T_{10} (429.0g). The observations taken at the time of harvest showed that stem and root weight was significantly higher (102.3 and 66.67g) with application of 100 per cent fertigation of recommended dose of macro nutrients using water soluble fertilizers given at weekly interval (T_3) than all other treatments, which was followed by T_4 and T_7 (94.00 g) for stem and T_4 (46.33 g) and T_7 (45.67 g) for the root weight. The lower values for stem (38.3, 45.0 g) and root (26.33, 32.67 g) were observed with soil application of fertilizers (T_1) and fertigation with common fertilizers (T_2), respectively. Naher

et al., (2014) recorded maximum root and stem weight at the time of harvest with NPK fertilization. This might be due to extended split application of nitrogen and potassium fertilizers up to 60 DAT increased the use efficiency of added nutrients which enhanced the uptake of these nutrients resulted more vegetative growth.

The head diameter of cabbage is a vital parameter which influences the head size and its market value. Larger diameter of head fetches better market quality of cabbage as well as processing (Table 3). The significantly higher head diameter was recorded with T_3 (13.30 cm), which remained on par with only T_4 (12.88 cm) and T_7 (12.99 cm), while T_1 recorded the lowest values for head diameter (9.93 cm). Higher uptake of nutrients may have resulted in higher diameter of head. These results are in conformity with the findings of Sharma *et al.,* (2004), Shinde *et al.,* (2006) and Tanpure *et al.,* (2007).

The weight of individual head is also an important parameter which ultimately decides the yield of the cabbage crop (Table 3). The individual head weight was also significantly influenced by different treatments. Most of the fertigation treatments with application of water soluble fertilizers remained on par with each other. However, the maximum head weight was observed with T_3 (454.0 g) followed by T_7 (423.6 g) and T_4 (357.3 g). The treatments, T_{10} (238.4 g), T_1 (234.0 g) and T_2 (237.3 g) had produced significantly lower head weight than T_3.

Increased nutrient availability in the root zone due to optimum nutrition levels leads to greater absorption and translocation of minerals and nutrients and finally increased accumulation of photosynthates by plants, might be the reasons for higher head weight. These results are corroborated with the findings of Shinde *et al.,* (2006), Tanpure *et al.,* (2007), Imtiyaz *et al.,* (1999), Kumar and Sahu (2013), Mohapatra *et al.,* (2013), Verma *et al.,* (2014), Kumari *et al.,* (2015) and Mankar *et al.,* (2015).

Irrespective of dosage and source of fertilizer, fertigation treatments were significantly superior to conventional soil application treatment with respect to yield. All the fertigation treatments recorded higher yields over the conventional soil application of fertilizers to the tune of 6.5 – 60.3 per cent. Among the fertigation treatments, application of 100 per cent fertilizer dose using water soluble fertilizers at weekly interval (T_3) resulted in significantly higher yield (60.86 t ha^{-1}) than all the other treatments except the treatment T_7, where the bi-weekly application of same amount of fertilizer through the same sources (58.82 t ha^{-1}) and T_4 *i.e* 100 per cent fertilizer dose, but 50 % N and K was applied through water soluble fertilizers (56.94 t ha^{-1}) was done. Reducing the dosage of NK or NPK fertigation by 25 per cent reduced the yield substantially.

The interaction of inherent and extraneous factors decides the yield levels of a particular crop. It includes production and mobilization of carbohydrates, water and nutrients uptake from the soil and several other environmental factors to which plants are exposed during the growing period.

Application of nutrients through water soluble fertilizers at different crop growth stages helps in meeting out the nutritional requirements which leads to better and luxurious growth resulted in higher light interception and photosynthates translocation from source to sink for the enhanced yields. These results are in agreement with those reported by Shinde *et al.,* (2006) in cabbage, Kapoor *et al.,* (2014), Chetan and Singh (2011) in cauliflower and Nair *et al.,* (2017) in okra.

Table.1 Fertigation treatment details in cabbage

Symbol	Treatment	Fertilizer	Application dose	Basal dose (kg ha^{-1})	Top dressing (kg ha^{-1})	Fertigaton (kg ha^{-1})	Frequency
T_1	100 % fertilizer dose (150:100:125 Kg ha^{-1})	Common	100 % soil application	75:100:62.5	75:100:62.5	-	-
T_2		Common	50 % NK fertigation	75:100:62.5		75:0:62.5	Weekly
T_3		WSF	100 % NPK fertigation			150:100:125	Weekly
T_4		WSF	50 % NK fertigation	75:100:62.5		75:0:62.5	Weekly
T_5	75 % fertilizer dose (112.5:75:93.75 kg ha^{-1})	WSF	100 % NPK fertigation			112.5:75:93.75	Weekly
T_6		WSF	50 % NK fertigation	56.25:75:46.87		56.25:0:46.87	Weekly
T_7	100 % fertilizer dose (150:100:125 Kg ha^{-1})	WSF	100 % NPK fertigation			150:100:125	Bi-weekly
T_8		WSF	50 % NK fertigation	75:100:62.5		75:0:62.5	Bi-weekly
T_9	75 % fertilizer dose (112.5:75:93.75 kg ha^{-1})	WSF	100 % NPK fertigation			112.5:75:93.75	Bi-weekly
T_{10}		WSF	50 % NK fertigation	56.25:75:46.87		56.25:0:46.87	Bi-weekly

WSF: Water soluble fertilizers

Table.2 Treatment wise fertilizers applied (Kg ha^{-1}) under fertigation in cabbage

Treatments	Basal dose			Top dressing		Fertigation			
	Urea	Single super phosphate	Muriate of potash	Urea	Muriate of potash	Urea	Muriate of potash	Sulphate of potash	19 All
T_1	163.0	625.0	104.0	163.0	104.0	-	-	-	-
T_2	163.0	625.0	104.0			163.0	104.0	-	-
T_3	0.0	0.0	0.0			109.0		50.0	526.0
T_4	163.0	625.0	104.0			163.0		125.0	-
T_5	0.0	0.0	0.0			81.0		38.0	395.0
T_6	67.5	90.0	45.0			122.0		94.0	-
T_7	0.0	0.0	0.0			109.0		50.0	526.0
T_8	163.0	625.0	104.0			163.0		125.0	-
T_9	0.0	0.0	0.0			81.0		38.0	395.0
T_{10}	67.5	90.0	45.0			122.0		94.0	-

Table.3 Growth and yield parameters of cabbage as influenced by fertigation treatments (Pooled data)

Treatment	At 60 DAT		At harvest							WUE (kg/ha-mm)	FUE (Kg/kg)
	Plant height (cm)	Plant spread (cm)	Leaves per plant	Leaves weight per plant (g)	Head weight (g)	Head diameter (cm)	Stem weight (g)	Root weight (g)	Yield (t ha^{-1})		
T_1	23.59	30.65	17.67	360.0	234.0	9.93	38.3	26.33	37.96	79.08	**101.23**
T_2	24.74	32.26	18.67	395.0	237.3	10.76	45.0	32.67	40.39	84.14	**107.71**
T_3	29.56	38.33	25.67	599.3	454.0	13.30	102.3	66.67	60.86	126.79	**162.29**
T_4	29.23	34.27	25.00	586.0	357.3	12.88	94.0	46.33	56.94	118.62	**151.84**
T_5	28.76	33.77	23.33	541.6	341.0	11.96	73.3	39.00	52.59	109.56	**187.15**
T_6	26.01	32.46	21.67	459.7	288.3	11.72	70.0	34.33	51.74	107.79	**184.13**
T_7	29.34	37.47	25.33	583.3	423.6	12.99	94.0	45.67	58.82	122.54	**156.85**
T_8	28.80	34.61	23.67	568.6	351.7	12.43	88.3	44.33	52.41	109.18	**139.76**
T_9	26.82	33.82	22.33	539.0	338.0	11.78	72.7	37.33	49.72	103.58	**176.94**
T_{10}	26.09	32.53	20.00	429.0	238.4	11.51	65.6	33.33	47.06	98.04	**167.47**
CD (*P*=0.05)	**0.780**	**3.26**	**4.59**	**140.16**	**187.7**	**0.472**	**28.79**	**13.35**	**4.06**		

Table.4 Economics of cabbage crop in relation to fertigation treatments

Treatment	Average Yield (t ha^{-1})	Gross Investment (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	Benefit :cost ratio
T_1	37.96	160822	379600	218778	**1.36**
T_2	40.39	160822	403900	243078	**1.51**
T_3	60.86	190800	608600	417800	**2.19**
T_4	56.94	166437	569400	402963	**2.42**
T_5	52.59	180587	525900	345313	**1.91**
T_6	51.74	162296	517400	355104	**2.19**
T_7	58.82	190800	588200	397400	**2.08**
T_8	52.41	166437	524100	357663	**2.15**
T_9	49.72	180587	497200	316613	**1.75**
T_{10}	**47.06**	**162296**	**470600**	**308304**	**1.90**

Sale Price = Rs.10.00/kg

Application of 100 per cent fertilizer dosage through water soluble fertilizers at weekly (T_3) or bi-weekly (T_7) interval did not bring significant differences in head yield of cabbage crop and it remained same with 75 per cent of the dosage *i.e*. T_5 and T_9. However, reducing the dosage by 25 per cent and applying it through water soluble fertilizers at weekly or bi-weekly interval made a significant difference in yield levels. Similarly, significant differences were recorded between application of 50 per cent of NK amount at 100 and 75 per cent fertilizer dosage through fertigation at weekly as well as bi-weekly intervals.

Water Use Efficiency

Data pertaining to water use efficiency in cabbage is presented in Table 3. It is clearly evident from the results that all the fertigation treatments using water soluble fertilizers produced higher water use efficiency to the tune of 6.39 to 60.33 per cent compared to conventional method of fertilizer application (79.08 kg/ha-mm). Among fertigation treatments,T_3 *i.e.* application of 100 per cent NPK fertigation using water soluble fertilizers on weekly basis, recorded the highest water use efficiency of 126.79 kg/ha-mm followed by same amount of fertilizer given on bi-weekly basis (T_7 :122.54 kg/ha-mm). This was mainly due to maximum cabbage head yield recorded with same amount of irrigation water used. This is in confirmation with the findings of Kapoor *et al.,* (2014) in cauliflower, Chand (2014) in salad cucumber, Soumya *et al.,* (2008) in tomato, Mahendran *et al.,* (2011) and Nair *et al*., (2017) in okra. Cutting across the level and frequency of fertigation, NPK fertigation in general resulted in marginally superior water use efficiency (109.18 - 126.79 kg/ha-mm) over NK fertigation treatments (98.04 - 109.56 kg/ha-mm).

Fertilizer use efficiency

Though the T_3 recorded highest yield (60.86 t ha^{-1}) and water use efficiency (126.79 kg/ha-mm), the application of 25 per cent less amount of fertilizer dosage in the form of water soluble fertilizes given either 100 per cent NPK of 50 per cent NK on weekly and bi-weekly basis through fertigation resulted in higher fertilizer use efficiency (167.47 to 187.15 kg/kg). Soil application or fertigation with normal fertilizers gave the minimum values for fertilizer use efficiency of 101.23 and 107.71 kg/kg. Vasu and Reddy (2013) also recorded higher fertilizer use efficiency at lower rate of fertilizer dose in cabbage.

Economics

The averaged data pertaining to economic returns and benefit: cost ratio related to 'Unnati' a cultivar of cabbage for the year 2013 and 2014 are given in Table 4. All the fertigation treatments with water soluble fertilizers resulted in higher gross income than soil application (T_1) and fertigation with common fertilizers (T_2). Among the fertigation treatments, application of 100 per cent fertilizer dose through fertigation on weekly basis (T_3) has resulted in highest gross income (Rs.608600 ha^{-1}) followed by T_7 *i.e.* same amount of fertilizer given on bi-weekly basis (Rs.588200 ha^{-1}). As far as net income is concerned, the higher values were recorded with T_3 (Rs.417800 ha^{-1}) and T_4 (Rs.402963 ha^{-1}). Fertigation of 50 per cent amount of N and K of the 100 per cent fertilizer dose through water soluble fertilizers (T_4) has recorded the highest B:C ratio of 2.42. This is mainly due to less gross investment coupled with moderately higher levels of yield compared to other treatments. Because of this, in other treatments, wherever 50 per cent amount of N and K applied through fertigation and reaming 50 per cent through soil application resulted in moderately higher

B:C ratio, which ranged from 1.90 to 2.19, irrespective of weekly or bi-weekly applications. Vasu and Reddy (2013) and Bhoutekar *et al.*, (2017) recorded higher B:C ratio with higher doses of fertilizer where the N and K was given through fertigation in cabbage and cauliflower, respectively. Nair *et al.*, (2017) also observed the same results in okra.

From this study it can be concluded that application of water soluble fertilizers @150:100:125 kg NPK ha^{-1} during the cropping period through fertigation at weekly intervals resulted in higher yield and net income in *rabi* grown cabbage. However, higher B:C ratio was obtained with fertigation of 75:0:62.5 NPK ha^{-1} at weekly intervals along with soil application of 75:100:62.5 NPK ha^{-1} as basal dose.

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