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Effect of fertigation on yield, quality, nutrient uptake, fertilizer and water use efficiency in cabbage *(Brassica oleracea)*

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Abstract

A field experiment was conducted to study the effect of fertigation on yield, quality, nutrient uptake, fertilizer and water use efficiency in cabbage. Cabbage yield was highest (16.92 t ha^{-1}) and was also associated with higher content of N (3.18%) and K (4.60%) under daily fertigation of N and K (100% recommended dose) followed by the treatment comprising of 125% recommended dose. The highest N (100.50 kg kg^{-1}) and K (131.37 kg kg^{-1}) fertilizer use efficiency was recorded in daily fertigation of 75% RDF of N and K but highest water productivity (7.92 kg m^{-3}) was found with daily fertigation with 100% RDF. Uptake of N (146.65 kg ha^{-1}) and K (189.41 kg ha^{-1}) and head diameter (14.40 cm), TSS(4.66%) and ascorbic acid (118.37mg 100 g^{-1}) content was highest at 125% RDF but B:C ratio of 3.03 was recorded in daily fertigation with 100% RDF.

Additional key words: *Fertigation, nutrient uptake, fertilizer use efficiency, water productivity.*

Introduction

Vegetables are perhaps the most intensively irrigated crops in all over the world and more so is cabbage. It is one of the important energy vegetable crops throughout the world and 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). It is the fourth most widely grown vegetable crop in India and is cultivated in 0.37 M ha producing 8.53 MT with the productivity of 23 t ha^{-1} and occupies 4% of the total vegetable area (National Horticultural Board 2014). Efficient use of water and fertilizer is highly critical to sustain the agricultural production, more particularly in the context of declining per capita land and water availability, pollution and increasing cost of fertilizers. Drip irrigation helps in maintaining optimum soil moisture in the root zone with increased yield and water use efficiency. A significant goal of soil fertility research is to develop practices by which crop nutrient requirements are satisfied through maximum uptake of nutrients from minimum quantity of applied fertilizers. Fertigation is an efficient method of applying fertilizer through irrigation water as a carrier and distributor of crop nutrients holds key under these circumstances (Bachchhav 2005). Here, the soil is not considered as a storage reservoir for applied fertilizer but the fertilizer is applied to the soil to match the rate of nutrient uptake by the crop. This can be accomplished

by the daily application of fertilizers in required quantities through irrigation water. Furthermore, it would enable supply of nutrients and water in the center of root system (Rajaraman and Pugalendhi 2013). Despite the widespread use of high frequency irrigation system and fertigation elsewhere, in India not much information is available on different aspects of fertigation on closely grown crops like cabbage. Hence, an experiment was conducted to study the effect of fertigation on yield, quality, nutrient uptake, fertilizer and water use efficiency in cabbage.

Materials and Methods

The experiment was conducted at Water Technology Centre, ANGRAU, Hyderabad (17° 19' N, 78°24' E and 542.6 m AMSL). The experimental soil is sandy clay loam (pH 7.4) characterized by low in available N (254.1 kg ha^{-1}) and available P_2O_5 (19.1 kg ha^{-1}) but high in available K_2O (324 kg ha^{-1}). The total rainfall received during crop growth period was 45.0 mm in 6 rainy days. The experiment was laid out in a Randomized Block Design, consists of 10 treatments *viz*., soil application of RDF of N and K (T_1), 125% RDF of N & K through fertigation at daily interval (T_2), at 3 days interval (T_3), at weekly interval (T_4), 100% RDF of N & K through fertigation at daily interval (T_5), at 3 days interval (T_6), at weekly interval (T_7), 75% RDF N & K through fertigation at daily interval (T_8), at 3 days interval (T_9), at weekly interval (T_{10}) and all the treatments were replicated thrice. The recommended fertilizer dose is 100 : 125 : 100 kg N, P_2O_5 and K_2O ha^{-1} respectively. The plot size was 7.2 m x 3.6 m and 30 days old seedlings of cabbage (Golden Acre) were transplanted with a spacing of 45 x 45 cm.

Drip system for fertigation was laid out and the laterals of 16 mm diameter were laid 1.2 m apart with spacing of 45 cm distance between two inline emitters. The emitter discharge was 4 L hr^{-1} and at the joints control taps were fixed in all laterals to facilitate imposition of different treatments. The quantity of water applied through drip was calculated based on the following formula (Richard *et al.* 1998) and applied at each time.

$$Vm = Kc \times Kp \times Cc \times Ep \times A$$

Vm = monthly irrigation water requirement (L)

Kc = crop coefficient factor

Cc = canopy factor

Crop factor (Kc)

15 days after planting	0.4
30 days days after plating	0.8
45 days after planting	1.15
60 days after planting	0.7

Ep = normal monthly pan evaporation

A = Area (ha)

The irrigations were scheduled at 100 percent E pan in furrow system. At each irrigation, 50 mm water was given and quantity of water was calculated using the formula.

$$W = A \times d \times 1000$$

Where ,

W = Quantity of water (m^3)

A =Plot area in m^2

d = Depth (mm)

Fertigation treatments were imposed by dissolving the required quantity of urea and muriate-of-potash as per treatment and applied through ventury to the field. The recommended quantity of phosphorus (through SSP) was applied to soil as basal. Nitrogen was applied in two splits at 15 and 45 DAT and entire quantity of P and K was applied as basal for T_1. Dry matter yield of cabbage was determined by randomly collecting plants (without roots) at vegetative stage (30 DAT), head initiation stage (60 DAT) and harvest stage along with cabbage head. The samples were dried at 65°C for 48 h and weighed. Cabbage yield (fresh weight) was determined at the time of harvest. Dried plant samples were powdered and digested with triacid mixture consisting of HNO_3: H_2SO_4 ; $HClO_4$ (9:3:1). Nitrogen (Micro-kjeldhal method, AOAC, 1965), phosphorus (Vanado molybdo phosphoric acid yellow color method, Piper 1966), potassium (Flame photometer, AOAC, 1965) were estimated by standard pro-

cedures. Nutrient uptake was estimated by multiplying nutrient content with total dry matter yield. Total soluble solids was determined with the help of 'Erma" hand refractometer (range 0-32%) and was corrected at 20°C with help of temperature correction table (AOAC, 1965). Ascorbic acid content of cabbage was determined using 2,6- dichloro phenol dye (Highet and West 1942). Fertilizer use efficiency was determined as the ratio of cabbage yield to quantity of fertilizer. Water productivity was estimated as the ratio of cabbage yield (kg) to the total water (m^3) applied.

Results and Discussion

Cabbage yield and quality

Fertigation with 125% recommended dose of N & K at daily interval (T_2) and 100% of N & K at daily interval (T_5) resulted in higher dry matter production of 4793 and 4553 kg ha^{-1} respectively (Table 1). It may be due to the fact that the native soil was low in nitrogen and application of nutrients through drip fertigation might have resulted in increased availability of nutrients and in-turn higher dry matter production. Similar results were also reported in cabbage (Lingaiah *et al.* 2005). Highest cabbage yield (16.92 t ha^{-1}) was recorded with application of 100% recommended dose of N and K through fertigation at daily interval (T_5) followed by T_2 with 15.53 t ha^{-1} (Table 1). Treatments T_5 and T_2 were statistically at par in increasing the yield of cabbage. Tanpure *et al.* (2007) and Kumar *et al.* (2013) also reported similar results in cabbage. Application of 75% recommended dose of N & K through fertigation with daily and 3 days interval (T_8 & T_9) and 125% RDF N & K through fertigation with 3 days interval (T_3) produced 13.05, 12.03 and 13.49 t ha^{-1}, respectively which were on par with each other.

Table 1. Dry matter and yield of cabbage as influenced by fertigation

Treatment	Dry matter yield (kg ha^{-1})			Yield
	30 DAT	60 DAT	Harvest	(t ha^{-1})
T_1 : Soil application of N,P,K (100% RDF)	2083	2763	3417	8.53
T_2 : 125% RDF N & K at daily interval	3007	4103	4793	15.53
T_3 :125% RDF N & K at 3 days interval	2623	3297	4157	13.49
T_4 : 125% RDF N & K at weekly interval	2463	3150	3877	10.23
T_5 : 100% RDF N & K at daily interval	3330	3930	4553	16.92
T_6 : 00% RDF N & K at 3 days interval	2927	3347	4440	11.88
T_7 : 100% RDF N & K at weekly interval	2663	3457	4107	9.53
T_8 : 75% RDF N & K at daily interval	3160	3623	4010	13.05
T_9 : 75% RDF N & K at 3 days interval	2373	2883	3607	12.03
T_{10} : 75% RDF N & K at weekly interval	2260	2660	3047	9.55
S.Em±	240	260	210	0.94
CD (0.05)	710	780	620	2.35

T_1 –Furrow irrigation; T_2-T_{10} –Fertigation treatments; DAT –Days After Transplanting

Table 2. Nutrient uptake as influenced by fertigation in cabbage

Treat-ments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest
T_1	61.64	84.40	106.21	3.41	4.52	5.85	67.15	102.38	114.98
T_2	102.64	125.72	146.65	7.96	8.68	10.30	105.23	161.86	189.41
T_3	80.56	112.43	130.69	4.64	5.95	8.54	77.37	124.31	169.06
T_4	76.53	100.22	125.67	4.33	5.45	7.92	79.05	122.76	164.08
T_5	98.00	123.06	143.41	7.19	8.52	9.83	101.11	148.45	178.43
T_6	91.71	116.34	138.15	5.35	6.17	9.08	99.63	138.28	184.86
T_7	77.44	103.19	125.64	4.20	5.38	8.20	83.28	127.74	139.69
T_8	95.42	120.05	134.67	5.91	7.35	9.90	95.35	130.22	170.27
T_9	66.11	86.59	109.26	3.66	4.46	6.12	72.32	96.93	139.76
T_{10}	65.58	87.50	101.96	3.68	4.27	5.59	67.01	88.05	124.31
S.Em±	7.51	8.45	10.25	0.55	0.61	0.61	8.30	11.38	8.14
CD (0.05)	22.48	25.31	20.71	1.65	1.82	1.82	20.87	24.07	26.37

Table 3. Quality parameters as influenced by fertigation in cabbage

Treatments	Head diameter (cm)	Head weight (g)	Heading percentage	Ascorbic Acid content (mg 100 g^{-1})	Total Soluble Solids (%)
T_1	10.60	483	90.41	80.03	2.66
T_2	14.40	877	95.66	118.37	4.66
T_3	10.86	753	94.38	107.95	3.53
T_4	10.76	720	93.10	98.28	3.20
T_5	13.26	923	96.75	112.27	3.93
T_6	13.26	846	94.91	100.23	3.56
T_7	11.90	707	94.29	91.76	3.43
T_8	11.66	826	96.60	102.35	3.36
T_9	11.76	760	93.13	95.56	2.93
T_{10}	10.73	503	92.87	92.54	2.90
S.Em±	0.26	30.81	1.03	3.52	0.11
CD (0.05)	0.90	90.06	NS	10.56	0.32

Application of 125 % of RDF of N and K through fertigation at daily interval (T_2) resulted in the highest head diameter (14.40 cm) followed by 3 days interval (T_6) and 100 per cent of recommended dose of N and K at daily interval (T_5) with 13.26 cm. The highest individual cabbage head weight (923 g) was recorded in 100% RDF of N & K through fertigation at daily interval (T_5) and followed by T_2 with 877 g (Table 3). Marsic and Osvald (2004) reported that fertigation of N and K resulted in high average weight of cabbage head.

The highest TSS content (4.66%) was observed in T_2 followed by T_5 with 3.93% owing to application of higher dose of fertilizers (Table 3). The highest ascorbic acid content (118.37 mg 100 g^{-1}) in cabbage was found in T_2 followed by T_5 (112.27 mg 100 g^{-1}). Potassium fertigation resulted in higher ascorbic acid content (38 mg 100 g^{-1}) when K was applied in the form of SOP than soil application of KCl in tomato (Kaviani *et al.* 2004).

Table 4. Fertilizer use efficiency and water productivity as influenced by fertigation in cabbage

Treatments	Fertilizer use efficiency (kg kg^{-1})			Water productivity
	Nitrogen	Phosphorus	Potassium	(kg m^{-3})
T_1	39.32	10.92	51.40	3.49
T_2	49.90	17.32	65.23	6.34
T_3	49.75	17.27	65.04	5.52
T_4	40.18	13.09	52.53	4.19
T_5	78.00	21.66	101.96	7.92
T_6	54.69	15.19	71.50	4.85
T_7	43.94	12.20	57.44	3.89
T_8	100.50	20.93	131.37	5.34
T_9	76.41	15.91	99.71	4.92
T_{10}	58.67	12.22	76.70	3.91
S.Em±	5.94	1.60	7.75	0.42
CD (0.05)	14.79	4.80	23.22	1.27

T_1- Furrow irrigation; T_2 – T_{10} – Fertigation treatments

Nutrient uptake

Increasing the quantity of fertilizers and fertigation frequency led to increase in nitrogen uptake irrespective of the crop stage. At vegetative stage the highest nitrogen uptake (102.64 kg ha^{-1}) was recorded with T_2 followed by T_5 (98.00 kg ha^{-1}). However, fertigation with 3 days interval and weekly interval resulted in nitrogen uptake on par with each other irrespective of the quantity of fertilizers applied through fertigation. At harvest, the total nitrogen uptake (146.65 kg ha^{-1}) was highest in T_2 followed by T_5 (143.41 kg ha^{-1}). Total N uptake was found to be higher in fertigation than broadcast application of fertilizers in potato (Battilani *et al.* 2008). Fertigation has profound effect on P uptake in vegetative and head initiation stages but not in harvest stage. Levels of N and K fertigation did not affect P uptake in cabbage from soil. At vegetative stage daily fertigation with T_2, T_5 and T_8 treatments registered higher P uptake of 7.96, 7.19 and 5.91 kg ha^{-1} respectively (Table 2). The higher P uptake may be due to frequent application of water

leadind to its higher availability near root zone. At harvest stage, there was no subsequenst effect of fertigation on P uptake. The highest K uptake at vegetative stage was observed in T_2 (105.23 kg ha^{-1}) and it was on par with T_5 (101.11 kg ha^{-1}). Increasing the K level in fertigation increased the K uptake in tomato (Kaviani *et al.* 2004). At harvest, higher total K uptake was recorded in treatments with higher doses of fertilizers. Highest total uptake of K was recorded in T_2 (189.41 kg ha^{-1}) and it was on par with T_3 (169.06 kg ha^{-1}), T_4 (164.08 kg ha^{-1}), T_5 (178.43 kg ha^{-1}) and T_6 (184.86 kg ha^{-1}). Similar results were reported by Thompson *et al.* (2003).

Table 5. Economics of fertigation in cabbage

Treatments	Cost of cultivation Rs ha^{-1}	Gross Returns Rs ha^{-1}	Net Returns Rs ha^{-1}	B:C Ratio
T_1	40343	85300	44957	1.11
T_2	42457	155300	112843	2.66
T_3	41857	134900	93043	2.22
T_4	41357	102300	60943	1.47
T_5	41943	169200	127257	3.03
T_6	41343	118800	77457	1.87
T_7	40853	95300	54447	1.33
T_8	41428	130500	89072	2.15
T_9	40828	120300	79472	1.95
T_{10}	40328	95500	55172	1.37

Cost of inputs:		**Labour charges:**		**Output cost;**
Urea	Rs.270 / 50 kg	Men	Rs.150 / 8 hr	Cabbage Rs.10.0 kg^{-1}
SSP	Rs.360 / 50 kg	Women	Rs.100/ 8 hr	
MOP	Rs.850 / 50 kg	Tractor	Rs.1500 / 8 hr	

Fertilizer and water use efficiency

The highest N fertilizer use efficiency (100.50 kg kg^{-1}) was recorded with fertigation of N at daily interval with 75% recommended dose nitrogen (T_8) followed by T_5 with 78.00 kg kg^{-1} and T_9 with 76.41 kg kg^{-1}. Since T_8 had same level of yield with T_5, it saves 25% of fertilizer. As higher yield was recorded in T_5 and T_8 their N fertilizer use efficiency was higher. The highest K fertilizer use efficiency (131.37 kg kg^{-1}) was recorded with fertigation of K at daily interval with 75% recommended dose of potassium (T_8) followed by T_5 (100% RDF of K) with 101.96 kg kg^{-1} and T_9 (75% RDF of K at 3 days interval) with 99.71 kg kg^{-1} (Table 4). The highest water productivity (7.92 kg m^{-3}) was recorded in daily fertigation with 100% RDF (T_5) followed by T_2 and T_3 with 6.34 and 5.52 kg m^{-3} respectively. Shinde *et al.* (2006) recorded water use efficiency with daily fertigation in cabbage while Doltra *et al*. (2008) reported highest water productivity (23.0 kg m^{-3}) in cabbage with high level of N fertigation. Daily fertigation with 100% N and K (T_5) resulted in the highest gross return (Rs.1,69,200 ha^{-1}), net return (Rs.1,27,257 ha^{-1}) and benefit- cost ratio of 3.03 (Table 5).

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