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Response of Knolkhol cv. Early White Vienna to Drip Irrigation and Fertigation in Kashmir Region

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Abstract: The experiment consisted of sixteen treatment combinations and replicated four times in a factorial randomized block design. The treatments include four levels of irrigation and fertilizer application. The growth and yield characteristics of knolkhol cv. Early White Vienna were significantly influenced by drip irrigation and fertigation levels. However, the treatment combination of 80% ET through drip (40.04 cm) + 80% recommended NPK (100:48:64 kg ha^{-1}) through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application. It was further concluded that the treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K) was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

***Key Words*:** Drip irrigation, fertigation, water use efficiency, fertilizer use efficiency, knolkhol

Knolkhol (*Brassica oleracea* cv. *gongylodes* L.) is a temperate vegetable and very popular in Kashmir region. Although Kashmir is rich in its water resources and there are several methods of providing irrigation to vegetable crops, yet drip irrigation is very useful for the region, because most of the orchard crops exist in the uplands where the scarcity of water is felt largely by the farmers throughout the year. Drip irrigation can be very effectively utilized in such land situations of the region. The research work on adoption of drip irrigation and fertigation practices in different vegetable crops revealed the efficiency of the system in reducing the water and fertilizer requirement with increased yield. However, very little literature is available pertaining to performance of knolkhol under drip system. The results of the present study revealed a significant and positive response of knolkhol under drip irrigation and fertigation system. In view of importance of drip irrigation system and need for its diversification, the present study was conducted to assess the performance of knolkhol for increased yield and effective use of irrigation water and fertilizers for Kashmir region.

MATERIAL AND METHODS

The present investigation was carried out at the Experimental Farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). Factorial randomized block design was followed with sixteen treatment combinations and four replications. The treatments comprised of four levels of irrigation *viz*. 100%, 80% & 60% ET through drip and 100% surface irrigation; and 4 levels of fertilizers application such as 100%, 80% & 60% recommended NPK through fertigation and 100% recommended NPK through traditional approach. Surface irrigation and manual application of fertilizers were treated as control. The volume of water required under drip irrigation system was computed using following equation: V = [DE x CF x AA x PC]/IE

Where, V= Volume of water required (l plant^{-1} day^{-1}), DE = Daily pan evaporation (mm), CF = Crop factor, AA = Area allotted per plant (m^2), PC = Pan coefficient and IE = Irrigation efficiency as a decimal. The crop factor (CF) is related to relative water demand to crop growth stages and the respective CF value for knolkhol was taken as 0.30, 0.60, 0.95 and 0.80, respectively for initial, development, mid-season and during late-season stage. The pan factor value was 0.75 as suggested for USDA class-A pan. The area allotted per plant was 0.12 m^2.

Twenty-two days old seedlings of knolkhol cv. Early White Vienna were transplanted on 22nd September 2007 with 6 rows per plot keeping row to row and plant to plant distance of 30 and 40 cm, respectively. Drip system was laid out parallel to the crop rows and each lateral with emitter distance at 40 cm and 2.2 l h^{-1} discharge rate. The amount of water actually applied by way of drip irrigation was based on climatologically approach and pan evapo-transpiration. Irrigation was scheduled on alternate day in case of drip irrigation and need based surface irrigation was applied. Fertigation with RFD 125:60:80 kg NPK ha^{-1} was given according to the treatments in eight split doses at ten days interval beginning 10 days after transplanting. However, in case of manual fertilizer application, half dose of nitrogen (as urea) and full doses of phosphorus (as SSP) and potassium (as MOP) were applied as basal doses while the remaining half dose of nitrogen was applied at 20 and 40 days after transplanting as top dressing. All the other packages and practices were adopted as recommended for the region (Anonymous 2005). Observations were recorded for various growth, yield and quality traits. Volumetric method was used for calculating the uniformity coefficient of drip irrigation system (Raina *et al.,* 1999). The water use efficiency was computed by dividing yield (q ha^{-1}) with total water applied (cm) including effective rainfall. The fertilizer use efficiency was worked out separately for N (NUE-nitrogen use efficiency), P (PUE-phosphorus use efficiency) and K (KUE-potassium use efficiency) by dividing total yield (q ha^{-1}) with total fertilizer applied (kg ha^{-1}).

RESULTS AND DISCUSSION

In order to check the efficiency of drip irrigation system, uniformity coefficient (UC) of drip irrigation system was worked out and was found to be 93.8%. The high value of UC indicates the excellent performance of the system in supplying water uniformly throughout the laterals.

Drip irrigation levels significantly influenced the growth and yield characteristics (Table 1). Drip irrigation at 80% ET proved significantly superior over other treatments by recording the maximum plant height (30.30 cm), no. of leaves plant^{-1} (14.09), plant spread (41.19 cm), leaf length (27.90 cm), leaf breadth (10.04 cm), knob length (6.11 cm), knob diameter (7.35 cm), root length (15.71 cm), root diameter (1.09 cm), average root weight (16.73 g), average leaf weight (11.20 g), average knob weight (328.09 g), gross weight per plant (486.1 g), knob weight (17.25 kg plot^{-1}) and knob yield (266.31 q ha^{-1}), whereas, the surface irrigation noticed minimum values for these mentioned characters with lowest yield (185.56 q ha^{-1}). The improved growth and yield of knolkhol under drip irrigation might be due to the regular availability of water around the root zone at very low moisture tension, reduced runoff and leaching losses, hence available fully to plants.

The response of various fertigation levels in knolknol cv. Early White Vienna showed that all the fertigation levels exhibited significant improvement in various growth and yield characters in comparison to manual fertilizer application (Table 2). However 80% recommended NPK through fertigation produced maximum values for plant height (28.72 cm), no. of leaves/plant (13.48), plant spread (42.02 cm), leaf length (26.62 cm), knob length (5.62 cm), knob diameter (6.75 cm), average knob weight (305.35 g), grass weight plant^{-1} (426.0 g), knob weight plot^{-1} (16.02 kg) and knob yield (248.26 q ha^{-1}) whereas 100% recommended NPK through fertigation recorded maximum leaf breadth (9.71 cm), root length (15.53 cm), root diameter (1.03 cm), average root weight (15.84 g) and average leaf weight (10.60 g). The minimum knob yield (207.82 q ha^{-1}) was found with the manual fertilizer application. Fertigation allows more controllable application of nutrients during the crop growing season and also restricts leaching losses of nutrients as compared to other methods of fertilizers application including traditional broadcasting method, and hence realizes higher yield. Increased growth and yield of cabbage, lettuce and cauliflower under fertigation system was earlier reported by Titular (1995).

Combined drip irrigation and fertigation, supply and maintain an optimum level of both moisture and nutrients within the root zone, with irrigation water acting as a vehicle for the nutrients required by the crop. The results of the present study confirm the superiority of combined effect of drip irrigation and fertigation over their individual effects in knolkhol (Table 3). The treatment combination of 80% ET through drip + 80% recommended NPK was found best among all other treatment combinations with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that control. The same treatment combination also recorded maximum plant height, no. of leaves plant^{-1}, plant spread, knob length, diameter and weight, gross weight plant^{-1}. However, leaf length, leaf breadth, root length, root diameter, average root weight and average leaf weight registered maximum values with the treatment combination of 80% ET through drip + 100% recommended NPK through fertigation. Our findings are in accordance with the findings of Rubeiz *et al.* (1989) and Burnette *et al.* (1993) in cabbage and broccoli, Hochmuth *et al.* (1994) in lettuce, Thompson *et al.* (2000) in cauliflower and Ristimaki *et al.* (2000) in cabbage.

Water use efficiency: Results obtained revealed that drip irrigation substantially decreased the consumptive use of water in knolkhol in comparison with surface irrigation (Table 1 and Table 4). Drip irrigation at 100%, 80% and 60% ET consumed 50.05, 40.04 and 30.03 cm ha^{-1} water throughout the cropping season; while the surface irrigated plots consumed 66.2 cm ha^{-1} water and saving of irrigation water in the tune of 24.3%, 39.5% and 54.6%, respectively through drip irrigation over surface irrigation, leading to a significant increase in water use efficiency. However, the maximum water use efficiency (8.07 q ha^{-1} cm) was observed with 60% ET though drip followed by 80% ET through drip (6.65 q ha^{-1} cm) and 100% ET through drip (4.58 q ha^{-1} cm), whereas, the lowest water use efficiency (2.80 q ha^{-1} cm)

Table 1. Effect of drip irrigation on growth, yield and water use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight. plot^{-1} (kg)	Knob yield (q ha^{-1})	Water applied (cm)	WUE (q ha^{-1} cm)
I_1	26.58	11.75	39.29	27.15	9.53	4.88	5.97	15.20	0.94	15.74	10.63	273.93	356.9	14.79	229.37	50.05	4.58
I_2	30.30	14.09	41.19	27.90	10.04	6.11	7.35	15.71	1.09	16.73	11.20	328.09	486.1	17.25	266.31	40.04	6.65
I_3	27.83	13.15	40.48	24.05	8.43	5.24	6.47	13.47	0.83	12.44	8.60	290.84	401.0	15.70	242.36	30.03	8.07
I_4	22.81	10.06	35.79	21.99	7.48	3.75	4.74	12.55	0.75	10.02	7.46	222.77	278.2	12.02	185.56	66.2	2.80
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation

Table 2. Effect of fertigation on growth, yield and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (q ha^{-1})	NUE (q kg^{-1} N)	PUE (qkg^{-1} P)	KUE (qkg^{-1} K)
F_1	25.90	11.88	39.43	27.20	9.71	4.86	5.89	15.53	1.03	15.84	10.60	272.04	371.1	14.68	226.69	1.81	3.77	2.83
F_2	28.72	13.48	42.02	26.62	9.34	5.62	6.75	14.99	0.97	15.20	10.27	305.35	426.0	16.02	248.26	2.48	5.17	3.87
F_3	27.85	13.03	41.12	24.86	8.60	5.28	6.33	13.90	0.85	13.29	9.19	288.93	399.5	15.60	240.83	3.21	6.68	5.01
F_4	25.05	10.66	35.19	22.40	7.82	4.22	5.56	12.50	0.77	10.60	7.83	249.30	325.5	13.46	207.82	1.66	3.46	2.59
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-	-

*F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

Table 3. Effect of drip irrigation and fertigation on growth and yield characters of knolkhol cv. Early White Vienna

Treatment combination*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root wt. (g)	Av. leaf wt. (g)	Av. knob wt. (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (qha^{-1})
I_1F_1	25.57	11.73	39.31	28.80	10.13	4.57	5.67	16.07	1.03	17.50	11.70	267.22	334.40	14.43	222.77
I_1F_2	28.87	13.33	41.98	28.07	9.80	5.67	6.67	15.73	0.99	16.87	11.50	293.51	422.90	15.85	244.68
I_1F_3	27.20	12.47	40.17	26.97	9.33	5.07	6.05	15.17	0.94	15.60	10.60	285.74	366.80	15.43	238.17
I_1F_4	24.70	9.47	35.79	24.77	8.87	4.23	5.00	13.83	0.83	13.00	8.73	249.25	303.80	13.46	207.87
I_2F_1	29.07	13.27	41.67	29.77	11.10	6.13	7.45	16.93	1.37	18.50	12.50	322.70	504.00	17.42	268.80
I_2F_2	32.20	15.20	44.77	29.30	10.47	6.60	7.90	16.53	1.18	18.33	12.00	377.80	537.00	18.24	281.50
I_2F_3	31.40	14.97	43.97	27.33	9.67	6.33	7.63	15.33	0.97	16.30	11.20	325.18	510.40	17.56	270.98
I_2F_4	28.53	12.93	38.46	25.23	8.93	5.40	6.03	14.07	0.89	13.80	9.10	292.70	393.00	15.81	243.99
I_3F_1	26.33	12.07	39.82	26.10	9.43	4.90	5.87	14.87	0.93	14.87	10.00	267.90	357.30	14.46	223.13
I_3F_2	29.93	14.20	43.19	25.83	9.20	6.05	7.10	14.50	0.90	14.50	9.70	321.29	445.90	17.35	267.87
I_3F_3	29.33	13.77	42.67	22.90	7.77	5.80	6.83	12.87	0.79	12.00	7.73	319.07	430.30	17.23	265.99
I_3F_4	25.73	12.60	36.37	21.40	7.33	4.23	5.10	11.67	0.70	8.40	7.00	255.10	370.80	13.77	212.49
I_4F_1	22.63	10.47	36.99	24.17	8.20	3.87	4.59	14.27	0.82	12.50	8.23	230.37	289.00	12.44	192.07
I_4F_2	23.90	11.20	38.22	23.30	7.90	4.17	5.33	13.20	0.81	11.13	7.90	234.81	298.50	12.68	195.80
I_4F_3	23.47	10.93	37.80	22.27	7.67	3.95	4.83	12.27	0.73	9.27	7.23	225.74	290.80	12.19	188.23
I_4F_4	21.27	7.67	30.33	18.23	6.17	3.03	4.23	10.47	0.67	7.20	6.50	200.18	234.50	10.81	166.97
CD(0.05)	3.35	1.79	3.01	2.81	1.36	0.63	0.80	1.57	0.02	1.49	1.45	59.8	27.49	3.23	49.84

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation
F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

Table 4. Effect of drip irrigation and fertigation on yield enhancement, water and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment combination*	Yield (q ha^{-1})	Increase in yield (%)	Water applied (cm)	Water saving (%)	WUE (q ha^{-1} cm)	Fertilizer applied (NPK kg ha^{-1})	Fertilizer saving (%)	Fertilizer use efficiency		
								NUE (q kg^{-1} N)	PUE (q kg^{-1} P)	KUE (q kg^{-1} K)
I_1F_1	222.77	33.3	50.05	24.3	4.45	125:60:80	-	1.78	3.71	2.78
I_1F_2	244.68	46.5	50.05	24.3	4.96	100:48:64	20	2.48	5.18	3.88
I_1F_3	238.17	42.6	50.05	24.3	4.75	75:36:48	40	3.17	6.61	4.96
I_1F_4	207.87	24.4	50.05	24.3	4.15	125:60:80	-	1.66	3.46	2.59
I_2F_1	268.80	60.9	40.04	39.5	6.17	125:60:80	-	2.15	4.48	3.36
I_2F_2	281.50	68.5	40.04	39.5	7.03	100:48:64	20	2.81	5.86	4.39
I_2F_3	270.98	62.2	40.04	39.5	6.76	75:36:48	40	3.61	7.52	5.64
I_2F_4	243.99	46.1	40.04	39.5	6.09	125:60:80	-	1.95	4.06	3.04
I_3F_1	223.13	39.6	30.03	54.6	7.43	125:60:80	-	1.78	3.71	2.78
I_3F_2	267.87	60.4	30.03	54.6	8.92	100:48:64	20	2.67	5.58	4.18
I_3F_3	265.99	59.3	30.03	54.6	8.85	75:36:48	40	3.54	7.38	5.54
I_3F_4	212.49	27.2	30.03	54.6	7.07	125:60:80	-	1.69	3.54	2.65
I_4F_1	192.07	15.0	66.20	-	2.90	125:60:80	-	1.53	3.20	2.40
I_4F_2	195.80	17.2	66.20	-	2.95	100:48:64	20	1.95	4.07	3.05
I_4F_3	188.23	12.7	66.20	-	2.84	75:36:48	40	2.50	5.22	3.92
I_4F_4	166.97	-	66.20	-	2.52	125:60:80	-	1.33	2.78	2.08

* See table 3 for details

was found with surface irrigation. More benefits of water use efficiency were observed with the combined application of drip irrigation and fertigation. Among various treatment combinations, 60% ET through drip + 80% recommend NPK though fertigation recorded maximum water use efficiency (8.92 q ha^{-1} cm). Since the rate of water losses through evaporation, percolation and leaching was much lower under drip irrigation, hence water use efficiency was higher as compared to surface irrigation. These results are in agreement with the earlier findings of Sharanappa *et al.* (2000), Thompson *et al.* (2000), Anil *et al.* (2001) and Gupta *et al.* (2010).

Fertilizer use efficiency: Among different fertigation levels, fertigation with 60% recommended NPK saved a considerable amount (40%) of fertilizers with maximum fertilizer use efficiency (NUE-3.21 q kg^{-1} N, PUE-6.68q kg^{-1} P and KUE-5.01 q kg^{-1} K) (Table 2 and 4). In case of combined application of drip irrigation and fertigation, the treatment combination of 80% ET through drip + 60 % recommended NPK through fertigation recorded the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K). Fertilizer use efficiency under drip irrigation and fertigation system might have increased due to higher and readily availability, the efficient use of nutrients at various stages of crop growth and practically no leaching of nutrients in the form of runoff. Similar benefits of fertilizers use efficiency were also reported by Everaarts (1993) in broccoli, Kaniszewski *et al.* (1999) in white cabbage, Thompson *et al.* (2000) in cauliflower and Gupta *et al.* (2009) in sprouting broccoli.

It was concluded that the treatment combination of 80% ET through drip + 80% recommended NPK through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application (166.97 q ha^{-1}). The treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

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