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Studies on irrigation regimes and fertility levels for kalonji (*Nigella sativa* L.) under South-Eastern Rajasthan

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ABSTRACT

An experiment was conducted during three consecutive years of rabi (2016-17 to 2018-19) at Agricultural Research Station, Ummedganj, Agriculture University, Kota (Rajasthan) on Kalonji (Nigella sativa L.). The experiment consisted of nine treatment combinations viz. three irrigation regimes (IW/CPE ratio 0.4, 0.6 and 0.8) and three levels of fertility (75, 100 and 125 % RDF) were under taken in split plot design with four replications. The maximum plant height, branches and yield attributes was recorded with irrigation regime of IW/CPE 0.8 over application of IW/CPE 0.6 and IW/CPE 0.4 in the pooled analysis. Pooled data showed that the significantly higher seed yield (890 kg ha^{-1}), net return (Rs. 1,27,270 ha^{-1}) and B: C ratio (4.40) of kalonji was obtained under the application of irrigation regime IW/CPE 0.8 as compared to IW/CPE 0.4. While, maximum water use efficiency (39.1 kgha-mm^{-1}) and water productivity (3.91 kg m^{-3}) was recorded under irrigation regime IW/CPE 0.4 in comparison to irrigation regime IW/CPE 0.8. Under application of 125 % RDF was recorded maximum plant height, number of branches and yield attributes over application of 75 % RDF, but it was found at par with application of 100 % RDF. Among the fertility levels, the maximum seed yield (850 kg ha^{-1}) of kalonji, water use efficiency (39.8 kg ha-mm^{-1}), net return (Rs. 1,20,470 ha^{-1}) and B: C ratio (4.15) was found in application of 125 % RDF being on par with 100 % RDF over application of 75 % RDF in the pooled data. Similarly, maximum water productivity (3.97 kg m^{-3}) was recorded under application of 125 % RDF in comparison to 75 % RDF.

Keywords: Economics, fertility levels, irrigation regimes, kalonji and water use efficiency.

INTRODUCTION

Nigella (*Nigella sativa* L.) is an annual aromatic plant and one of the important seed spices crop. It is mainly grown in winter season under irrigated as well as rainfed conditions. In India, it is cultivated in Rajasthan, Uttar Pradesh, West Bengal, Punjab, Himachal Pradesh, Jharkhand, Madhya Pradesh, Andhra Pradesh and Assam. In India nigella is cultivating in 4.29 lakh hectare area, producing 1.72 lakh tonnes of seed with an average productivity of 402 kg ha^{-1} (Goswami, 2011). Black cumin seed is an expensive spice, commonly used for culinary purpose and beverages. The specially used in cheese and bakery products preparation, seed also have various medicinal properties and are widely used in Ayurveda and other ethnomedicine systems all over the world (Padmaa, 2010). Black cumin seed contains 21% protein, 35 % carbohydrates, 35-38 % oils, 3.8-5.3 % total ash, ash insoluble in acid 0-0.5%, volatile oil 0.5-1.6 %, oleic acid 3.4-6.3%, essential amino acids, vitamins and minerals (Ahmad and Ghafoor, 2007).

The successful cultivation of black cumin depends upon various factors *viz*., fertilizer nutrient management, irrigation and cultural practices etc. Presently, developing of sustainable agricultural practices along with increase in yield is the need of hour.In the south eastern plain zone of Rajasthan, the kalonji is grown in a small-scale basis but, it has a great potentiality. Irrigation is the most limiting factor for kalonji production especially in the *rabi* season under non command area of the zone. Therefore, irrigation should be scheduled on critical stages of water requirement (Bannayan *et al.,* 2008). Moreover, deficit irrigation is the one way of maximizing water use efficiency for higher yields per unit of irrigation water applied where crop is exposed to a certain level of water stress either during throughout the entire growing season (English and Raja, 1996). Irrigation scheduling based on developmental stage is the technique of applying water on a

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timely and accurate basis to the crop (Bannayan *et al.,* 2006).

Plant nutritional constraint often restricts yield and qualities of crops. Growth and yield of nigella are largely influenced by fertility status of the soil apart from genetic potential of the variety. Altering the soil nutrients and fertility status by providing balanced and adequate major nutrients like nitrogen, phosphorus and potassium as per the crop requirement is one of the easiest ways to enhance crop productivity. Nitrogen and phosphorus had significant effect on yield and quality of nigella (Mollafilabi *et al.,* 2009).

MATERIALS AND METHODS

An experiment was conducted on Kalonji *(Nigella sativa* L.*)* during three consecutive years of *rabi* (2016-17 to 2018-19) at Agricultural Research Station, Ummedganj, Kota, which is situated at South-Eastern part of Rajasthan. In Rajasthan, this region falls under Agro-climatic zone Vth B humid south eastern plains of Rajasthan. It is located between 25^{0}13´ N latitude and 75^{0} 25´ E longitudes at an altitude of 258 m above mean sea level. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 20.8 °C to 38.0 °C and 04.0 °C to 23.0 °C during *rabi* season. The soil of experimental site was clay loam in texture, slightly alkaline in reaction. The experimental soil was medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha^{-1}) while high in potassium (388 kg ha^{-1}) with pH (7.6) and EC (0.52 dS m^{-1}). Source of nutrients were applied urea for nitrogen, DAP for phosphorus and mutate of potash for potassium. The full dose of fertilizer 100 % RDF (30: 60: 25 NPK kg ha^{-1}) was applied as basal dose and irrigation was applied as per irrigation regimes of the experiment.

The experiment consisted of nine treatment combinations viz. three irrigation regimes (IW/CPE ratio 0.4, 0.6 and 0.8) allocated in main plots and three levels of fertility (75, 100 and 125 % RDF) in sub plots were under taken in split plot design with four replications. Data on seed yield, water use efficiency, water productivity, net returns and B: C ratio were recorded as per standard procedures. The data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

Methodology for measuring of IW/CPE ratio

The irrigation scheduling is based on the cumulative pan evaporation and irrigation depth. Irrigation at ratio of irrigation water (IW) and cumulative pan evaporation (CPE). IW /CPE = depth of water to be irrigated/Cumulative pan evaporation for particular period. For example, for ten days cumulative pan evaporation at the rate of 10 mm per day equal to 100 mm (CPE). Irrigation depth to be given is 50 mm. Therefore IW/CPE ratio is 50 mm (depth) /100 mm (CPE) = 0.5.

Like this many ratio have to be tried and find the best yield performing rabi which can be adopted for scheduling irrigation. The irrigation depth (IW) for different crops are fixed based on the soil and climatic condition. The ratio of IW / CPE which gives relatively best yield is fixed for each crop by experiment with different ratio. The irrigation depth (IW) divided by the ratio (R) will give the cumulative pan evaporation value at which irrigation is to be made. For example, the irrigation depth (IW) needed is 50 mm and the ratio (R) to be tried is 0.5. Therefore, the cumulative pan evaporation value needed to irrigated the field is IW/R i.e. 50/0.5 = 100 mm. If the 100 mm of CPE is attained in 10 days (pan evaporation @ 10 mm per day), once in 10 days irrigation is to be given.

Water use efficiency (kg ha-mm^{-1})

Irrigation water use efficiency was estimated as the ratio of seed yield (kg/ha) and irrigation water applied (mm) based on below formula.

Water use efficiency (kg ha-mm^{-1}) = Seed yield (kg/ha) /Irrigation water applied (mm)

Water productivity (kg m^{-3})

Water productivity is defined most often as the average amount of yield per unit of water applied on a field or per unit of water evapotranspiration.

Water productivity (kg m^{-3}) = Yield (kg/m^{3})/ Water applied (m^{3}/ha)

RESULTS AND DISCUSSION

Effect of irrigation regimes on growth parameters

A perusal of three years pooled data presented in Table 1 showed that the application of increasing levels of irrigation regimes significantly increases growth parameters *i.e.* plant height and number branches of kalonji. The maximum plant height at 60, 90 DAS and at harvest (31.2, 71.5 and 102.8 cm) of kalonji was recorded at irrigation regime 0.8 IW/CPE ratio over application of irrigation at 0.6 IW/CPE (28.5, 67.1 and 94.6 cm) and 0.4 IW/CPE ratio (26.8, 64.4 and 86.2 cm) in the pooled analysis. Significantly higher number of primary and secondary branches in kalonji (11.2 and 16.80) was recorded under irrigation regime of 0.8 IW/CPE ratio over application of 0.6 IW/CPE ratio (9.11 and 14.10) and 0.4 IW/CPE ratio (8.60 and 11.15).

The plant height, number of primary and secondary branches increased with the increasing levels of irrigation. These results may be due to the effect of short watering intervals, plants received sufficient moisture to enhance the rates of physiological processes and increasing the hydrostatic pressure on the cell wall, which is necessary for the enlargement of cell. Hence, enhancement of the assimilated food and increase the cell elongation and division consequently, the whole growth of plant as well as branching could be increased (Bouton *et al.,* 1985). The growth characters of black cumin were maximum at 0.8 IW/CPE due to higher physiological activities favouring higher nutrient uptake and photosynthesis which might be responsible for formation of more photosynthesis, resulting more yields (Lakpale *et al.,* 2007).

Table 1: Effect of irrigation regimes and fertility levels on pooled data of growth parameters, yield attributes and seed yield of kalonji (2016-17 to 2018-19)

Treatment	Plant height (cm)			Branches ($Plant^{-1}$)		Capsules ($Plant^{-1}$)	Seeds ($Capsule^{-1}$)	Test weight (g)	Seed yield (kg ha^{-1})
	60 DAS	90 DAS	At harvest	Primary	Secondary				
A. Irrigation regimes									
IW/CPE 0.4	26.8	64.4	86.2	8.60	11.15	27.60	59.80	3.50	630
IW/CPE 0.6	28.5	67.1	94.6	9.11	14.10	31.20	64.50	3.63	820
IW/CPE 0.8	31.2	71.5	102.8	11.22	16.80	35.62	70.12	3.82	890
SEm ±	0.68	1.22	1.75	0.70	0.75	1.02	1.45	0.057	22.0
CD (P=0.05)	2.02	3.52	5.18	1.98	2.18	2.98	4.20	0.170	66.0
B. Fertility levels									
75 % RDF	27.4	65.1	91.8	8.80	11.65	29.80	62.50	3.59	660
100 % RDF	29.7	69.0	98.5	10.30	15.24	33.56	68.90	3.81	820
125 % RDF	30.9	71.8	101.2	11.29	17.20	36.10	71.32	3.88	850
SEm ±	0.66	1.16	1.72	0.67	0.73	0.99	1.39	0.054	27.0
CD (P=0.05)	1.96	3.40	5.10	1.95	2.10	2.90	3.90	0.160	76.0

Effect of irrigation regimes on yield attributes and yield

It is evident from three years pooled data presented in Table 1 showed that the application of increasing irrigation regimes significantly increases yield attributes and seed yield of kalonji. Significantly higher number of capsules $plant^{-1}$ (35.62), seeds $capsules^{-1}$ (70.12) and test weight (3.82 g) were recorded at irrigation regime 0.8 IW/CPE ratio over application of irrigation at 0.6 IW/CPE ratio and 0.4 IW/CPE ratio capsules $plant^{-1}$ (31.20 and 27.60), seeds $capsules^{-1}$ (64.50 and 59.80) and test weight (3.63 and 3.50 g) in the pooled data. The maximum seed yield of kalonji (890 kg ha^{-1}) was recorded at irrigation regime 0.8 IW/CPE ratio over application of irrigation at 0.6 IW/CPE (820 kg ha^{-1}) and 0.4 IW/CPE ratio (630 kg ha^{-1}) in the pooled analysis.

The yield of black cumin was recorded maximum at 0.8 IW/CPE due to higher physiological activities favouring higher nutrient uptake and photosynthesis which might be responsible for formation of more photosynthesis, resulting more yields (Lakpale *et* *al*., 2007). The supply of sufficient water from the soil might have helped in maintaining better substrate for photosynthetic activities in the leaves. It is well known fact that proper supply of moisture helps in maintaining high photosynthetic rate and turgidity, which could increase the cell elongation and its multiplication at much faster rate. The similar trend of significant difference in seed yield was also noticed amongst different irrigation treatments in nigella (Karim *et al.,* 2017).

Effect of irrigation regimes on water use efficiency and water productivity

A reference to pooled data presented in Table 2 showed that the water use efficiency and water productivity were recorded during experimentation in kalonji. The maximum water use efficiency (39.1 kgha-mm^{-1}) and water productivity (3.91 kg m^{-3}) were recorded under irrigation regime IW/CPE 0.4 in comparison to irrigation regime IW/CPE 0.8 (31.7 kg ha-mm^{-1}) and (3.17 kg m^{-3}), but it was found at par with irrigation regime at 0.6 IW/CPE (37.2 kg ha-mm^{-1}) and (3.72 kg m^{-3}) in kalonji. The irrigation water use efficiency depends on irrigation level. Irrigation scheduling provides water to the plants, which matches the crop evapotranspiration rate and provides optimum irrigation at critical growth stages, resulting in high water use efficiency (Mehta *et al.,* 2010). This increase in water saving might be due to the efficient use of water, which was applied to maintain the appropriate soil moisture along with the maximum yield obtained with the minimum quantity of water. Similar findings have also been reported by Datta and Chatterjee (2006) in fenugreek.

Table 2: Effect of irrigation regimes and fertility levels on pooled data of water use efficiency (kg ha-mm^{-1}), water productivity (kg m^{-3}) and monetary returns of kalonji (2016-17 to 2018-19)

Treatment	Water use efficiency (kg ha-mm^{-1})	Water productivity (kg m^{-3})	Net return (Rs. ha^{-1})	B: C ratio
A. Irrigation regimes				
IW/CPE 0.4	39.1	3.91	83081	3.04
IW/CPE 0.6	37.2	3.72	116202	4.12
IW/CPE 0.8	31.7	3.17	127270	4.40
SEm ±	1.2	0.12	3891	0.14
CD (P=0.05)	3.5	0.35	11560	0.41
B. Fertility levels				
75 % RDF	29.9	2.99	76653	3.27
100 % RDF	38.3	3.83	116535	4.14
125 % RDF	39.8	3.97	126712	4.15
SEm ±	1.2	0.12	4340	0.17
CD (P=0.05)	3.7	0.37	12895	0.48

Effect of irrigation regimes on monetary returns

A perusal of pooled data presented in Table 2 showed that the application of increasing irrigation regimes significantly increases monetary returns of kalonji. The minimum net return (₹ 83081 ha^{-1}) was obtained under irrigation regime IW/CPE ratio 0.4, which increased remarkably under increasing irrigation regimes up to IW/CPE ratio 0.8. The maximum net return (₹ 127270 ha^{-1}) was recorded at IW/CPE ratio 0.8 followed by IW/CPE ratio 0.6 (₹ 116202 ha^{-1}) in the pooled analysis. The pooled data showed that the significantly higher B: C ratio (4.40) was recorded under application of irrigation regime at 0.8 IW/CPE ratio followed by 0.6 IW/CPE ratio (4.12) over application of irrigation regime at 0.4 IW/CPE ratio (3.04). The seed yield of cumin significantly increases, which led to give more returns in cumin (Rao *et al.,* 2010). Irrigation at IW/CPE ratio 0.8 was found at par with 1.0 IW/CPE ratio, which was recorded significantly higher net returns and B:C ratio over 0.4 and 0.6 IW/CPE ratios in the cumin (Jat *et al.,* 2015).

Effect of fertility levels on growth parameters

A perusal of three years pooled data presented in Table 1.0 showed that the application of increasing levels of fertilizer significantly increases growth parameters *i.e.,* plant height and number of branches in kalonji. The maximum plant height at 60, 90 DAS and at harvest (30.9, 71.8 and 101.2 cm) in kalonji was recorded with application of 125 % RDF over application of 75 % RDF (27.4, 65.1 and 91.8 cm), respectively. However, it was found at par with application of 100 % RDF (29.7, 69.0 and 98.5 cm) in kalonji. Significantly higher number of primary (10.30 and 11.29 plant^{-1}) and secondary branches (15.24 and 17.20 plant^{-1}) were recorded under application of 100 and 125 % RDF, which were found significantly superior over application of 75 % RDF primary (8.80 plant^{-1}) and secondary (11.65 plant^{-1}) branches in kalonji. A significant improvement in plant growth attributes *viz*., plant height, secondary branches and dry weight was observed when nutrients was used as optimum dose. This positive effect observed might be due to continuous and steady supply of the nutrients throughout the growing period of crop at various stages. The similar results were obtained in coriander by Farooqui *et al*. (2009). According to Rana *et al*. (2012), application of $N_{60}P_{120}$ kg ha^{-1} gave the maximum growth of black cumin.

Effect of fertility levels on yield attributes and yield

It is evident from pooled data presented in Table 1 showed that the application of increasing levels of fertilizer significantly increases yield attributes and seed yield of kalonji. Significantly higher number of capsules (33.56 and 36.10) plant^{-1}, seeds (68.90 and 71.32) capsules^{-1} were recorded under application of 100 and 125 % RDF over application of 75 % RDF capsules (29.80) plant^{-1}, seeds (62.50) capsules^{-1} in kalonji. The maximum test weight (3.88 g) and seed yield (850 kg ha^{-1}) was recorded under application of 125% RDF over application of 75 % RDF (3.59 g) and (660 kg ha^{-1}). However, it was found at par with application of 100 % RDF (3.81 g) and (820 kg ha^{-1}) in the pooled analysis. Al-Saadi and Alhalabi (2012) also reported that application of NPK fertilizers significantly increased yield of black cumin. According to Rana *et al*. (2012), application of $N_{60}P_{120}$ kg ha^{-1} gave maximum yield of black cumin ha^{-1}. Girma and Taddesse (2013) was found that application of N_{100} and P_{50} kg ha^{-1} gave maximum dry matter yield and seed yield of white cumin.

Effect of fertility levels on water use efficiency and water productivity

A reference to pooled data presented in Table 2 showed that the water use efficiency and water productivity were significantly increase with increasing levels of fertilizer during experimentation in the kalonji. The maximum water use efficiency (39.8 kgha-mm^{-1}) and water productivity (3.97 kg m^{-3}) were recorded under application of 125 % RDF in comparison to 75 % RDF (29.9 kg ha-mm^{-1}) and (2.99 kg m^{-3}), respectively. However, it was found at par with application of 100 % RDF (38.3 kg ha-mm^{-1}) and (3.83 kg m^{-3}) of kalonji. The higher water use efficiency and water productivity with higher level of fertilizer might be due to a greater increase in seed production (Mehta *et al.,* 2010). Under lower fertilizer levels obtained lower water use efficiency and water productivity due to low availability of nutrients, which resulted in higher water use but minimum economic yield. Singh *et al.,* (2015) also revealed that the water productivity was improved by the optimum fertilizer levels against the lower levels.

Effect of fertility levels on monetary returns

A perusal of data presented in Table 2 showed that the application of increasing levels of fertilizer significantly increases monetary returns of kalonji. The minimum net return (₹ 76,653/- ha^{-1}) was obtained under application of 75 % RDF, which increased remarkably under increasing levels of fertilizer up to 125% RDF. The maximum net return was recorded (₹ 1,26,712/- ha^{-1}) with application of 125 % RDF followed by 100 % RDF (₹ 1,16,535/- ha^{-1}) in the pooled analysis. The pooled data showed that the significantly higher B: C ratio (4.15) was recorded under application of 125 % RDF followed by 100% RDF (4.14) over application of 75 % RDF (3.27).

The fertilizer doses were widely influenced the net return as well as benefit cost ratio. Meena *et al*. (2014) also found similar results in nigella get support to the present studies. The application of chemical fertilizer along with bio fertilizer can increase the output by many folds. Singh (2018) also reported reported that application of 100 % NPK and *Azotobacter* 5 kg ha^{-1} gave higher net returns and B:C ratio in cumin.

CONCLUSION

It is concluded that the application of irrigation schedule IW/CPE 0.8 gave significantly higher seed yield, water use efficiency, water productivity, net return and B: C ratio of kalonji as compared to IW/CPE 0.4. Application of 125 % RDF also recorded higher seed yield, water use efficiency, water productivity, net return and B: C ratio over 75 % RDF. Hence this irrigation regime and fertilizer level is proved as productive and beneficial. These levels of irrigation regime and fertilizer level may be passed on to the farmers for obtaining higher returns in the zone V^{th} of Rajasthan.

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