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Irrigation and nitrogen fertigation on quality and minerals parameters of garlic (*Allium sativum*) cultivar Solan Selection

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ABSTRACT

Improving bulb yield, minerals and quality is a major challenge in garlic bulb production. In this study, the effects of irrigation and nitrogen fertilization on the quality and mineral content of garlic cultivar Solan Selection were investigated. The research was conducted over two consecutive winter seasons in 2016-17 and 2017-18, utilizing 12 different treatment combinations in a Factorial Randomized Block Design with three replications. The results indicated that increased nitrogen input led to a significant improvement in total soluble solid (TSS) and dry matter yield, resulting in higher garlic bulb yields. Similarly, an increased irrigation schedule also improved TSS and dry matter yield in garlic bulbs. Furthermore, the interaction between irrigation schedule and nitrogen fertigation had a positive impact on TSS and dry matter yield across cropping seasons. Combining increased nitrogen input and irrigation further enhanced TSS and dry matter yield, although there was no significant improvement in dry matter content and mineral (N, P, K, Ca, Mg, and S) contents in garlic bulbs. The study also revealed a strong positive correlation between nitrogen input and irrigation schedule concerning quality and mineral contents. These findings suggest that adopting high nitrogen input practices (100% of RDN) with increased irrigation (IW/CPE=1.2) can enhance garlic cultivar Solan Selection's dry matter yield, quality, and mineral content.

Key words: Garlic, minerals, fertilization, irrigation, bulb

INTRODUCTION

Garlic (*Allium sativum* L.) is a monocotyledonous plant belonging to the family Amaryllidaceae, in the order Asparagales. It is native to Central Asia and is cultivated in temperate climates worldwide, with an annual production of 28 million tons on approximately 1.6 million hectares (Parreño *et al.*, 2023). China and India are the largest producers of garlic, accounting for 80% of the global production. The per hectare yield of garlic bulb can be increased by adopting proper agronomic package of practices like, timely sowing, proper spacing, resource use efficiency, scheduling of irrigation, besides these balance applications of nitrogen plays a vital role in the development of garlic. Fertilizer plays an important role in efforts to increase agricultural yields; its contribution is up to 24% of crop production (Crista *et al.*, 2014). The role of fertilizer application, especially nitrogen, is very important for plant growth. Móring *et al.* (2021) reported that nitrogen is considered the most important factor for the growth and development of plants; it is the building block for plant protoplasm and the chlorophyll molecule component for the photosynthesis process. According to Sahu *et al.* (2023), nitrogen fertilizers responsible for vegetative growth, increasing the number of cloves, increasing the number of leaves/plant, plant height and increasing garlic bulb yield. Irrigation and nitrogen play an important role in ultimate productivity of garlic. But due to intensification in agriculture and various anthropogenic factors, the farmers are facing scarcity of irrigation water thus, affecting the uptake of nutrients and productivity of the crop. Especially the uptake of N by crops is affected to a large extent by soil moisture. Being a shallow rooted crop, garlic needs light frequent irrigations for better growth and yield. Under limited and low moisture conditions supplemental irrigations are needed for satisfying the evapo-transpiration requirement as well as for better utilization of the other production inputs and thus, ensuring higher crop yield. The frequency of irrigation and the amount of water required are governed by various factors such as cultivar, soil types, season, distribution of rainfall and management practices. The importance of irrigation scheduling is that it enables the irrigator to apply

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exact amount of water to achieve the goal of increased irrigation efficiency (Imitiyaz *et al.*, 2000). Irrigation scheduling is the use of water management strategies to prevent over application of water while minimizing the yield loss due to water shortage or drought stress. Bhatti (2017) reported that the application of 1.2 IW/CPE ratio and supplied with 125 per cent N fertigation recorded the highest TSS (12.34 °B) over control in onion bulb. Similarly, this study also revealed that the highest bulb N (3.11 %), K (2.93 %) and total NPK uptake (127.09, 24.37 and 123.6 kg per ha) with the application of 125 per cent of RDN and irrigation at 1.2 IW/CPE. Keeping these facts in view, a study was therefore carried out to develop an efficient irrigation schedule and to evaluate the interactive effects of nitrogen and irrigation levels to achieve higher productivity and to determine total soluble solid (TSS) and mineral parameters (N, P, K, Ca, Mg, and S) in garlic bulb.

MATERIALS AND METHODS

This experiment was conducted in 2016-17 and 2017-18 cropping seasons in hill region at experimental farm of department of Soil Science and Water Management, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh to determine the effect of suitable irrigation schedule and nitrogen fertilizer level on garlic cultivar Solan Selection using a factorial randomized complete block design experiment in three replications. Hilly region is situated at 30° 52' N latitude and 77° 11' E longitude and elevation of 1175 m above mean sea level with average slope of 7-8 per cent. The study area falls in sub-temperate, sub-humid agro-climatic zone of Himachal Pradesh (Zone-II). The average annual rainfall of the region is about 1100 mm and about 75 per cent of it is received during the monsoon period. Winter rains are meager and received during the months of January and February. Field was leveled and sufficient provision was kept for drainage. Thirty six raised plots of dimension 3 m x 2 m were made. Cloves of healthy bulbs were dibbled 5-7 cm deep at spacing of 20 cm × 10 cm keeping their growing ends upwards. After sowing cloves were covered with the thin layer of soil for its proper germination. The investigated quality and minerals parameters included dry matter yield, dry matter content, TSS (°Brix), nitrogen, phosphorus, potassium, calcium, magnesium and sulphur contents. Representative soil samples from 0-15 and 15-30 cm depths were collected at the end of experimentation during both the years of study to ascertain the effect of different irrigation and nitrogen levels on soil organic carbon, available nitrogen, phosphorus and potassium (Table 1). Data on different parameters were compiled and tabulated in proper form for statistical analysis. The data recorded was analyzed by using MS-Excel and OPSTAT software. The mean values of data were subjected to Analysis of Variance as described by Panse and Sukhatme (2000) for using Factorial Randomized Block Design. A Pearson correlation coefficient was used to determine the effect of the irrigation schedule and nitrogen input management on the quality and mineral concentration in garlic bulb.

Table 1: Physico-Chemical properties of soil at the conclusion of two-year experimentation in experimental farm

Physico-chemical properties	2016-2017		2017-2018	
	0-15 cm	15- 30 cm	0-15 cm	15-30 cm
Sand (%)	62.25	65.28	62.25	65.28
Silt (%)	21.64	23.37	21.64	23.37
Clay (%)	16.11	11.35	16.11	11.35
Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Bulk density (Mg m^{-3})	1.32	1.34	1.32	1.34
pH	6.63	6.79	6.68	6.81
EC (dS m^{-1})	0.23	0.30	0.25	0.28
Organic Carbon (g kg^{-1})	16.07	10.24	16.94	11.68
Available N (mg kg^{-1})	105.4	102.3	106.8	102.7
Available P (mg kg^{-1})	21.6	20.8	22.5	21.8
Available K (mg kg^{-1})	150.4	145.2	168.2	165.7

RESULTS AND DISCUSSION

The experimental site soil was sandy loam in texture, neutral in reaction, low in available nitrogen, high in available phosphorus and medium to high in available potassium (Sahu *et al.* 2023).

Table 2: Effect of irrigation and nitrogen fertigation on dry matter content, dry matter yield and TSS of garlic bulb

Treatment	Dry matter content (%)			Dry matter yield (q/ha)			TSS (°Brix)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
I0N0	24.3	25.5	24.9	21.2	25.6	23.4	22.2	22.3	22.2
I1N0	24.8	26.0	25.4	24.3	28.3	26.3	22.5	22.5	22.5
I2N0	24.9	26.1	25.5	25.5	30.7	28.1	22.6	22.6	22.6
I3N0	25.0	26.4	25.7	27.1	33.4	30.3	22.7	23.0	22.8
I0N1	25.0	26.4	25.7	25.4	31.7	28.5	22.4	22.8	22.6
I1N1	25.0	26.5	25.7	29.5	36.0	32.8	22.5	22.6	22.5
I2N1	25.8	27.3	26.6	31.3	38.9	35.1	22.7	22.9	22.8
I3N1	27.0	28.5	27.8	33.6	42.2	37.9	22.8	22.8	22.8
I0N2	26.9	28.5	27.7	30.1	36.8	33.5	22.9	23.0	22.9
I1N2	27.1	28.7	27.9	36.1	43.2	39.7	23.0	23.1	23.0
I2N2	27.2	28.8	28.0	38.9	44.4	41.6	23.0	23.1	23.0
I3N2	27.3	28.9	28.1	41.0	45.9	43.5	23.0	23.1	23.0
Mean	25.9	27.3	26.6	30.3	36.4	33.4	22.7	22.8	22.7
Critical Difference at 5% level of significance									
Irrigation	NS	NS	NS	0.7	0.3	0.4	0.2	NS	0.2
Nitrogen	NS	NS	NS	0.6	0.3	0.3	0.2	0.2	0.2
Interaction	NS	NS	NS	1.1	0.6	0.6	NS	NS	NS

I0: Control, I1: (0.8 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (1.2 IW/CPE ratio), N0: Control, N1: 75% of RDN, N2: 100% of RDN, Note: Each irrigation schedules and nitrogen levels were calculated from averaged of values of treatment

Dry matter content and dry matter yield of garlic bulb

The observations recorded for dry matter content (%) of garlic bulb showed insignificant effect with regards to irrigation and N levels during both the years as well as pooled study (Table 2). Pooled analysis of the data showed that under irrigation levels, maximum dry matter content (27.2 %) was observed under I3 schedule. Among N levels, maximum dry matter content (28.0 %) was recorded under N2 level. In case of irrigation and nitrogen fertigation interaction, maximum dry matter content (28.1 %) was recorded under I3N2. An acquisition of the data in Table 2 showed significant effect of irrigation, N levels and their interaction on dry matter yield of garlic bulb during both the years of study. Under irrigation levels, significantly higher dry matter yield of bulb (33.9 and 40.5 q per ha) was recorded under I3 during both the years of study. Among N levels, significantly higher dry matter yield of garlic bulb (36.5 and 42.6 q per ha) was recorded under N2 during both the years of study. In case of interaction (I×N), significantly highest dry matter yield of bulb (41.0 and 45.9 q per ha) was recorded under I3N2 during both the years of study. Pooled analysis of data showed that the effect of irrigation and N levels was significant on dry matter yield of garlic bulb (Table 2). Under irrigation levels, significantly higher dry matter yield of garlic bulb (37.2 q per ha) was recorded with I3 schedule. Among N levels, significantly highest dry matter yield of garlic bulb (39.6 q per ha) was recorded with N2 level. The interaction effect (I×N) was also significant and significantly highest dry matter yield of bulb (43.5 q per ha) was recorded with I3N2 treatment combination. An acquisition of the data in Table 2 showed that effect of irrigation and N levels was statistically non significant but their interaction was significant on dry matter yield of garlic during both the years of study. Higher dry matter content at irrigation level I3 might be due to optimum soil moisture regimes throughout the growing period (Table 2). The increased dry matter content under N2 is due to proper availability of N. Similar are the findings of Girarden *et al.* (1985) who also observed an increase in dry matter content of crop with the application of optimum level of N probably due to increase in photosynthetic rate which is directly correlated with chlorophyll content of plant cell. Studies of Farooqui *et al.* (2009) also revealed that by increasing the dose of N in garlic, there was increase in dry weight of bulbs and cloves. Similar research has also been observed by Naruka (2000), Naruka and Dhaka (2001), Naruka *et al.* (2005) and Diriba *et al.* (2014) in garlic and Yadav *et al.* (2003) and Banafar and Gupta (2005) in onion. Verma *et al.*, (2014) highlighted that the application of 100% NPK + 20 kg S ha-1 increased the bulb yield significantly by 63.3% over control.

TSS of garlic bulb

Perusal of the data in Table 2 revealed that the individual effect of irrigation and N levels on TSS content of garlic was significant but their interaction was insignificant during season 2016-17. Under irrigation levels, significantly higher TSS (22.8 °B) was observed under both I3 and I2 schedules. Under N levels, significantly highest TSS (23.0 °B) was observed under N2 level. During season 2017-18, the effect of N levels was significant but the effect of irrigation levels and their interaction were insignificant on TSS content of garlic. Under N levels, significantly highest TSS (23.0 °B) was observed under N2, which was statistically at par with N1 (22.8 °B). Pooled analysis showed that the effect of irrigation and N levels was significant on TSS of garlic (Table 2). Under irrigation levels, significantly higher TSS (22.9 °B) was recorded with I3 schedule. Under N levels, significantly highest TSS (23.0 °B) was recorded with N2 level. The interaction effect (I×N) was statistically insignificant on TSS content of garlic. Change in TSS with irrigation may be due to fulfillment of crop water demand and better utilization of nutrient under optimum moisture availability. It was observed that higher irrigation level significantly increased TSS content. The results are in consonance with the findings of Naruka and Dhaka (2001), Diriba *et al.* (2014) and Ahmed *et al.* (2009) in garlic. Sharma *et al.*, (2021) carried out field experiment to study the impact of organic and inorganic fertilizers on TSS of garlic. The maximum value of TSS (40.15 ^{o}Brix) was recorded under the 50 % of recommended dose of fertilizers, 2.5 tons vermicompost and 1.5 tons poultry manure per hectare.

Table 3: Effect of irrigation and nitrogen fertigation on nitrogen, phosphorous and potassium contents of garlic bulb

Treatment	Nitrogen content (%)			Phosphorous content (%)			Potassium content (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
I0N0	1.27	1.21	1.24	0.24	0.26	0.25	1.76	1.76	1.76
I1N0	1.46	1.38	1.42	0.25	0.28	0.26	1.78	1.78	1.78
I2N0	1.48	1.40	1.44	0.27	0.30	0.29	1.79	1.78	1.79
I3N0	1.48	1.42	1.45	0.28	0.31	0.30	1.82	1.80	1.81
I0N1	1.49	1.45	1.47	0.30	0.33	0.31	1.83	1.82	1.82
I1N1	1.47	1.46	1.46	0.32	0.33	0.33	1.84	1.83	1.84
I2N1	1.51	1.46	1.49	0.33	0.34	0.34	1.86	1.85	1.85
I3N1	1.57	1.53	1.55	0.34	0.35	0.34	1.87	1.85	1.86
I0N2	1.51	1.49	1.50	0.36	0.36	0.36	1.88	1.87	1.88
I1N2	1.57	1.52	1.55	0.36	0.37	0.37	1.90	1.89	1.89
I2N2	1.60	1.54	1.57	0.37	0.38	0.38	1.91	1.90	1.91
I3N2	1.65	1.60	1.63	0.38	0.39	0.39	1.93	1.92	1.92
Mean	1.51	1.46	1.48	0.32	0.33	0.33	1.85	1.84	1.84
Critical Difference at 5% level of significance									
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

I0: Control, I1: (0.8 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (1.2 IW/CPE ratio), N0: Control, N1: 75% of RDN, N2: 100% of RDN, Note: Each irrigation schedules and nitrogen levels were calculated from averaged of values of treatment

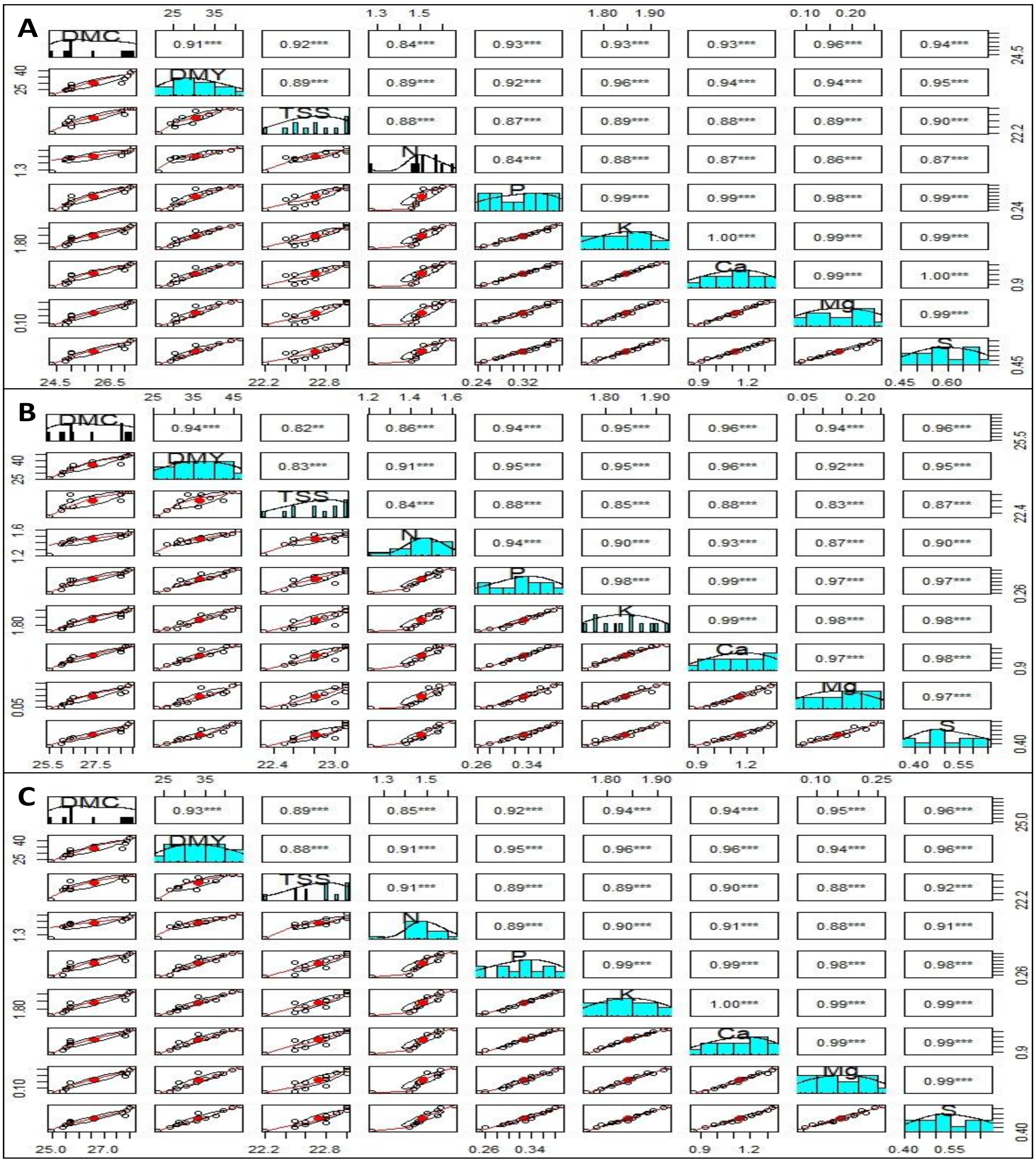

Figure 1: Pearson correlation coefficient among quality and minerals in garlic bulb. A) Cropping season 2016-17, B) cropping season 2017-18, and C) pooled over both the cropping seasons

Nitrogen content

The irrigation, N levels and their interaction had insignificant effect on bulb N content during both the years of study (Table 3). Pooled analysis of the data showed that under irrigation levels, higher bulb N content (1.54 %) was recorded under I3 schedule. Among the N levels, higher bulb N content (1.56 %) was observed under N2 level. In case of interaction (I×N) higher bulb N content (1.63 %) was recorded under I3N2 treatment combination. Ozkan *et al.*, (2018) highlighted that application of potassium and sulfur fertilizers did not altered nitrogen content s just prior to bulb initiation of onion leaves.

Phosphorus content

The irrigation, N levels and their interaction had insignificant effect on bulb P content during both years of study (Table 3). Pooled analysis of the data showed that under irrigation levels, higher bulb P content (0.34 %) was recorded under I3 schedule. Among the N levels, higher bulb P content (0.37 %) was observed under N2 level. In case of interaction (I×N), higher bulb P content (0.39 %) was recorded under I3N2 treatment combination. Ozkan *et al.*, (2018) highlighted that application of potassium and sulfur fertilizers did not altered nitrogen content s just prior to bulb initiation of onion leaves.

Potassium content

The irrigation, N levels and their interaction had insignificant effect on bulb K content during both the years of study (Table 3). Pooled analysis of the data showed that under irrigation levels, higher bulb K content (1.86 %) was recorded under I3 schedule. Among N levels, higher bulb K content (1.90 %) was observed under N2 level. In case of interaction (I×N) higher bulb K content (1.92 %) was recorded under I3N2 treatment combination. In contrast to present study, application of nitrogen fertigation significantly increase K content of the bulbs of *Lilium* species (Wang *et al.*, 2023).

Table 4: Effect of irrigation and nitrogen fertigation on calcium, magnesium and sulphur contents of garlic bulb

Treatment	Calcium content (%)			Magnesium content (%)			Sulphur content (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
I0N0	0.85	0.87	0.86	0.08	0.04	0.06	0.46	0.37	0.41
I1N0	0.91	0.96	0.93	0.09	0.05	0.07	0.49	0.40	0.45
I2N0	0.95	1.00	0.98	0.11	0.07	0.09	0.52	0.44	0.48
I3N0	1.02	1.06	1.04	0.13	0.09	0.11	0.54	0.46	0.50
I0N1	1.08	1.09	1.09	0.16	0.11	0.14	0.57	0.46	0.51
I1N1	1.11	1.14	1.13	0.15	0.13	0.14	0.58	0.47	0.52
I2N1	1.15	1.17	1.16	0.17	0.16	0.17	0.60	0.49	0.55
I3N1	1.19	1.23	1.21	0.21	0.16	0.19	0.62	0.53	0.58
I0N2	1.24	1.27	1.25	0.22	0.21	0.22	0.66	0.56	0.61
I1N2	1.28	1.32	1.30	0.24	0.18	0.21	0.68	0.59	0.63
I2N2	1.31	1.34	1.33	0.25	0.23	0.24	0.70	0.62	0.66
I3N2	1.35	1.36	1.35	0.26	0.25	0.26	0.72	0.65	0.68
Mean	1.12	1.15	1.14	0.17	0.14	0.16	0.60	0.50	0.55
Critical Difference at 5% level of significance									
Irrigation	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

I0: Control, I1: (0.8 IW/CPE ratio), I2: (1.0 IW/CPE ratio), I3: (1.2 IW/CPE ratio), N0: Control, N1: 75% of RDN, N2: 100% of RDN

Calcium content

It is evident from Table 4 that irrigation, N levels and their interaction had insignificant effect on bulb Ca content over both years and pooled study. Pooled analysis of the data revealed that under irrigation levels, highest bulb Ca (1.20 %) was recorded under I3 schedule. A mong N levels, highest bulb Ca (1.31 %) was observed under N2 level. In case of interaction (I×N) higher bulb Ca content (1.35 %) was recorded under I3N2 treatment combination. Ozkan *et al.*, (2018) highlighted that application of potassium and sulfur fertilizers did not altered calcium content at harvesting stage of onion.

Magnesium content

The perusal of data of irrigation, N levels their interaction had non-significant effect on bulb Mg content during both the years of study (Table 4). Pooled analysis of the data revealed that under irrigation levels, the highest bulb Mg (0.18 %) was recorded under I3 schedule. Among N levels, the highest bulb Mg (0.23 %) was observed under N2 level. In case of interaction (I×N) higher bulb Mg content (0.26 %) was recorded under I3N2 treatment combination. Jiku *et al.*, (2020) evaluated garlic cultivar under different levels of potassium in farm soils and found that there was no significant difference was found for nitrogen content in bulb.

Sulphur content

The irrigation, N levels their interaction had insignificant effect on bulb S content during both the years of study (Table 4). Pooled analysis of the data revealed that under irrigation levels, higher bulb S content (0.59 %) was recorded under I3 schedule. Among N levels, the highest bulb S content (0.65 %) was observed under N2 level. In case of interaction (I×N), higher bulb S content (0.68 %) was recorded under I3N2 treatment combination. It was observed that higher irrigation and N level increased the nutrient content in garlic bulb. The positive influence of the maximum irrigation and N level on nutrient content of bulb may be due to higher moisture level in the root zone and higher availability of nutrients; also increased the mobility of nutrients in the soil would have lead to increase in the minerals uptake by plant and increased carbohydrates assimilation. Increased accumulation of nutrients especially in vegetative plant parts possibly with improved metabolism led to greater translocation of these nutrients to bulb of the crop. These findings are in close agreement with other researchers i.e. Naruka and Dhaka (2001) and Ahmed *et al.* (2009) in garlic and Kemal (2013) in shallot. Quality and minerals concentration are key parameters for garlic bulb production and Pearson correlation coefficient between quality and minerals parameters are presented in Figure 1. The results showed that quality and minerals are positively correlated ($p<0.001$) with increasing irrigation scheduling and nitrogen input in garlic cultivation.

CONCLUSION

The study aimed to ascertain the effect of different irrigation schedules and N levels on quality and minerals parameters in garlic cultivar Solan Selection during two consecutive seasons 2016-17 and 2017-18. Dry matter yield of garlic bulb under I3 schedule (1.2 IW/CPE) was significantly higher over control. Interaction between irrigation schedule (1.2 IW/CPE) and increasing nitrogen input (100% of RDN) significantly enhanced dry matter yield in garlic bulb. The research also unveiled a strong positive association between nitrogen input and irrigation schedule in relation to the dry matter yield, quality and minerals. These findings suggest that adopting high nitrogen input practices (100% of RDN) with increased irrigation (IW/CPE=1.2) can enhance garlic cultivar Solan Selection's dry matter yield, quality, and mineral content.

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REFERENCES

Ahmed, M.E.M., Derbala, A. and Kader, N.A. (2009) Effect of irrigation frequency and potassium source on the productivity, quality and storability of garlic. Misr *Journal of Agriculture Engineering* 26:1245-1262.

Banafar, R.N.S. and Gupta, N.K. (2005) Effect of fertilizer mixture with and without sulphur on quality of onion. In: National Seminar on Agro-technology, Quality, Processing and Export of Spices. *JNKVV Jabalpur*. pp60.

Bhatti, S. (2017) Effect of different irrigation and nitrogen levels on the productivity of onion (*Allium cepa* L.). M. Sc. Thesis. Department of Soil Science and Water *Management, YSP University of Horticulture & Forestry, Solan*. 32p.

Crista, F., Boldea, M., Radulov, I., Lato, A., Crista, L., Dragomir, C., Berbecea, A., Nita, L. and Okros, A. (2014) The impact of chemical fertilization on maize yield. *Research Journal of Agricultural Science* 46(1): 172-177.

Diriba, S.G., Nigussie, D.R., Kebede, W., Getachew, T. and Sharma, J.J. (2014) Effect of nitrogen, phosphorous and sulphur fertilizers on growth, yield and economic returns of garlic (*Allium sativum* L.). *Science, Technology and Arts Research Journal* 4: 10-22

Farooqui, M.A., Naruka, I.S., Rathore, S.S., Singh, S.S. and Shaktawat, R.P.S. (2009) Effect of nitrogen and sulphur levels on growth and yield of garlic. Asian *Journal of Food and Agricultural Industries* S18-23.

Girardan, P., Tollennar, M. and Muldoon, J.F. (1985) Photosynthetic rate and chlorophyll content. *Canadian Journal of Plant Science* 65: 491-500.

Imtiyaz, M., Mgadla, N.P., Chepeter, B. and Manase, S.K. (2000) Response of six vegetable crops to irrigation schedules. *Agricultural Water Management* 45:331-342.

Jiku M.A.S., Alimuzzaman M., Singha A., Rahaman M.A., Ganapati R.K., Alam M.A. and Sinha S.R. (2020) Response and productivity of garlic (*Allium sativum* L.) by different levels of potassium fertilizer in farm soils. *Bulletin of the National Research Centre* 44: 1-9.

Kemal, Y.O. (2013) Effects of irrigation and nitrogen levels on bulb yield, nitrogen uptake and water use efficiency of shallot (*Allium cepa* var. *ascalonicum* Baker). *African Journal of Agriculture Research* 8:4637-4643.

Móring, A., Hooda, S., Raghuram, N., Adhya, T.K., Ahmad, A., Bandyopadhyay, S.K., Barsby, T., Beig, G., Bentley, A.R., Bhatia, A., Dragosits, U., Drewer, J., Foulkes, J., Ghude, S.D., Gupta, R., Jain, N., Kumar, D., Kumar, R.M., Ladha, J.K., Mandal, P.K., Neeraja, C.N., Pandey, R., Pathak, H., Pawar, P., Pellny, T.K., Poole, P., Price, A., Rao, D.L.N., Reay, D.S., Singh, N.K., Sinha, S.K., Srivastava, RK., Shewry, P., Smith, J., Steadman, C.E., Subrahmanyam, D., Surekha, K., Venkatesh, K., Singh, V.P., Uwizeye A., Vieno M. and Sutton, M.A. (2021) Nitrogen challenges and opportunities for agricultural and environmental science in India. *Frontiers in Sustainable Food Systems*, 5: 1-16.

Naruka, I.S. (2000) Effect of row spacing and nitrogen fertilization on growth, yield and quality of garlic cultivars. Ph. D Thesis, RAU, Bikaner.

Naruka, I.S. and Dhaka, R.S. (2001) Effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic (*Allium sativum* L.) cultivars. *Journal of spices and Aromatic crops* 10: 111-117.

Naruka, I.S., Singh, P.P., Rathore, S.S. and Singh, M.M. (2005) Response of garlic cultivars to nitrogen fertilization and crop geometry on composition of Seminar on Agro-technology, Quality, Processing and Export of Spices. *JNKVV Jabalpur*. pp52.

Ozkan, C.F., Anac D., Eryuce N., Demirta E.L.s, Asri F.Ö., Guven D., Simsek M. and Ari N. (2018) Effect of different potassium and sulfur fertilizers on onion (*Allium cepa* L.) yield and quality. e-ifc 53: 1-9.

Panse, V.G. and Sukhatme, P.V. (2000) Statistical Methods for Agricultural Workers. *Indian Council of Agricultural Research, New Delhi*. 381p.

Parreño, R., Rodríguez-Alcocer, E., Martínez-Guardiola, C., Carrasco, L., Castillo, P., Arbona, V., Jover-Gil, S. and Candela, H. (2023) Turning garlic into a modern crop: State of the art and perspectives. *Plants (Basel)*, 12(6):1212.

Sahu, K.K., Sharma, J.C. and Sanadya, S.K. (2023) Optimizing garlic (*Allium sativum*) yield through irrigation scheduling and nitrogen management. International *Journal of Plant & Soil Sciences* 35(20):1137-1144.

Sharma A., Asati K.P., Yadav S.S. and Namdev K.N. (2021) Impact of organic and inorganic fertilizers on growth, yield and economics of garlic (*Allium sativum* L.). *Annals of Plant and Soil Research* 23 (4): 477-480.

Verma D., Singh H., Singh N. and Shrama Y.K. (2014) Effect of inorganic fertilizers and fym on onion productivity and soil fertility. *Annals of Plant and Soil Research* 16(2): 117-120.

Wang Y., Bu H.,, Wang H., Zhang P. and Jin L. (2023) Effects of applying nitrogen and potassium on *Lilium lancifolium* Growth and accumulation of secondary metabolites in bulbs. *Horticulturae* 9(3): 1-14.

Yadav, R.L., Sen, N.L. and Yadav, B.L. (2003) Response of onion to nitrogen and potassium fertilization under semi-arid condition. *Indian Journal of Horticulture* 60: 176-178.