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Manifestation of improved cultivars, irrigation and sulphur in mustard growth, productivity, quality and profitability: A review

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Abstract
Globally, oilseed with second largest area and production holds the second position after cereals. Among oilseeds, mustard is the second best edible crop after groundnut but its average productivity is substantially lower than the global average which could be ascribed to lower use of agronomic inputs such as improved cultivars, irrigation and nutrient especially sulphur. Cultivars with differential genetic potential bring significant variation in growth and yield and hence, nutrient uptake by crop. Alteration in number of irrigation and levels of sulphur also produces subsequent effect in crop production especially mustard. This review attempts to provide an overview of manipulation in the concerned inputs under varied agro-climatic conditions and their individual and interactive effect on mustard.

Keywords: Mustard, irrigation regime, varieties, sulphur, productivity, profitability

Introduction

Oilseeds are one of the most important determinants (after cereals) of Indian agricultural economy making a contribution of 6 per cent in gross national product and 10 per cent in agricultural produce value. Rapeseed-mustard with production of 7.97 m ha from 6.37 m ha (DOAC, 2017) [2] occupies the second position among edible oilseeds after groundnut and is grown under different agro-ecosystem varying from rain-fed to irrigated, timely to late sown and sole as well as mixed crop. Though demand for vegetable oil is increasing with increase in population and improving living standards, but lower average productivity of mustard as compared to global average calls for intervention in mustard cultivation. Cultivation of mustard on inherently low-fertility fields with reduced or no use of additional inputs (irrigation, improved cultivars, nutrients) could be a possible explanation for its lower productivity (Ray *et al*. 2015) [35]. Among the different agronomic inputs, improved cultivar or hybrids present a viable option for increasing per unit area production because of their improved genetic potential. Furthermore, application of irrigation at regular interval with proper nutrient management is the other two most critical inputs which can substantially increase yield of mustard (Piri *et al.*, 2011) [31]. In addition to primary nutrients, sulphur as a constituent of amino acids, vitamins and sulpholipids, is observed to be imperative for yield and quality improvement in oilseeds including mustard (Morris, 2007; Singh and Pal, 2011) [21 40]. Therefore, this review attempts to provide an overview of the observed effect of the said inputs on the growth, yield, quality, nutrient uptake and economics of mustard under different agro-ecosystems.

Effect of irrigation regimes on growth, yield attributes and productivity of mustard

Since, mustard is predominantly a winter crop cultivated on residual moisture of south west monsoon with limited or no additional irrigation which restricts its yield to below potential; hence, proper irrigation scheduling could play a major role in enhancing growth of mustard. More favorable irrigation regimes maintained under regular watering results in higher soil moisture content in rhizosphere promoting cellular activity of enlargement, expansion and multiplication with synergistic impact on leaf water potential, stomatal conductance and photosynthetic activity. These conditions in conjunction enhances uptake, translocation and assimilation of nutrients facilitating increased plant height, higher leaves and branches plant^{-1}, leaf area index and dry matter accumulation. These beneficial effects of irrigation on growth parameters are also supported by following study:
In a study conducted by Yadav (2005) [44] in arid area of Bikaner, irrigation was observed to improve growth characters and application of irrigation at three stages of crop growth viz., branching, flowering and pod filling recorded higher plant height, dry matter accumulation

Plant^{-1}, chlorophyll content, number of primary and secondary branches plant^{-1}. Ghanbahadur and Lanjewar (2006) [5] observed higher number of siliquae plant^{-1}, pod length, number of seeds pod^{-1} and test weight with irrigation at 0.6 IW: CPE than at 0.4 IW: CPE resulting in increment of seed, stover and biological yield over 0.4 IW: CPE ratio.

Piri and Sharma (2006) [30] when made an assessment of effect of different irrigation regimes in north western plains vouched for the fact that increasing the frequency of irrigation from 0 to 2 and applying them at 30 and 60 DAS culminated in significantly better performance of mustard with respect to plant height, dry matter accumulation, secondary branches plant^{-1} and relative growth rate.

Meena (2011) [18] noted improvement in total number of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1}, test weight and seed yield with increasing IW/CPE ratio and maximum values of these parameters were recorded under 0.8 IW/CPE ratio. Parmar *et al*. (2016) [27] studied the yield attributing traits such as number of siliquae plant^{-1}, number of seeds siliquae^{-1}and 1000-seed weight as affected by irrigation regimes and found considerable increase in them with increase in IW: CPE ratio from 0.60 to 1.0.

Jat *et al*. (2018) [8] and Rathore *et al*. (2019) [33] in separate field experiments evaluated the effect of differential irrigation regimes and confirmed about the significant positive impact of irrigation on agronomic traits such as plant height, dry matter plant^{-1}, number of primary and secondary branches plant^{-1}

Effect of irrigation regimes on quality and nutrient uptake

At Jobner, in a field study by Kumawat (2004) [13], application of three irrigations at branching, flowering and siliqua development stages significantly increased N, P and K concentrations in seed and stover as well as their uptake in comparison to less frequent irrigation.

Similar effect of irrigation regimes was also noticed by Ghanbahadur and Lanjewar (2006) [5] who observed significantly higher uptake of both N and P in 0.6 IW: CPE ratio as compared to 0.4 IW: CPE.

Three irrigation given to mustard crop at branching, flowering and siliquae development stages recorded marked improvement in quality of seed and showed higher content of oil and protein in a study by Nagdive *et al*. (2007) [22]. Meena (2010) [19] observed that with application of three irrigations at branch initiation, 50% flowering and 50% pod development stages, significantly higher values of nitrogen content in seed and stover as well as nitrogen uptake by respective parts were noticed. Similar results were also reported by Meena (2011) [18] but irrigation regimes were based on IW/CPE ratio.

Ray *et al*. (2015) [35] in a study observed increase in glucosinolate with increasing irrigation levels and concluded that double irrigation recorded highest values of sinigrin, gluconapin and progoitrin along with maximum values for fatty acid thus bringing qualitative changes in mustard seed. Successive increment in oil content was noticed by Singh *et al*. (2018) [43] with increasing IW/CPE ratio from 0.2 to 0.4.

Effect of irrigation regimes on profitability

Enhanced growth and yield obtained under well irrigated condition ultimately results in higher profitability. In continuance to this, Mehta (2004) reported increment in net returns and benefit-cost ratio with increase in number of irrigations from 0-3 and found that mustard irrigated thrice at different stages gave highest net returns and B: C ratio in comparison to preceding levels of irrigation. While, Karoria (2008) [10] concluded that two irrigations provided at flowering and siliqua development stage result in maximum net returns and benefit cost ratio followed by crop with single irrigation at flowering stage.

Similarly in an experiment by Piri *et al*. (2011) [31] increase in irrigation frequency from nil to two reported to increase gross returns, net returns and B: C ratio and two irrigations gave highest net return and B: C ratio over one irrigation and no irrigation.

Parmar *et al*. (2016) [27] concluded that application of irrigation at higher IW/CPE ratio gave higher net returns in comparison to less frequent irrigation associated with lower IW/CPE ratio. Similar treatment also provided better production efficiency, profitability and relative economic efficiency. In another study, increase in number of irrigation in mustard brings increment in the cost of cultivation, gross and net income along with benefit: cost ratio and higher values were observed with application of irrigation thrice at 0-35 DAS, flowering and siliqua development (Shivran *et al*., 2018).

Effect of improved cultivars on growth, yield attributes and productivity

Improved cultivars and hybrids offers better genetic makeup, ensures uniform germination and emergence maintaining optimum plant stand, higher survival under temperature stress during vegetative phase, resistance to major pests and diseases and efficient translocation and assimilation of assimilates which ultimately results in improved growth, yield contributing characters and productivity of mustard as also supported by following:

Ghanbahadur (2002) [4] found superior performance of 'Pusa Bold' over other varieties with respect to plant height, number of leaves, leaf area and LAI. Goyal *et al*. (2006) recorded highest seed yield with variety Varuna followed by Kranti.

Singh *et al.* (2007) in Kanpur concluded that *'Varuna'* proved superior over *'Rohini', 'Kranti'* and *'Urvashi'* for plant height, dry matter m^{-1} row length and number of primary branches plant^{-1} and this superior performance in growth manifested in higher seed yield of *Varuna'* over remaining varieties.

Scrutiny of observations by Kumari (2009) [15] revealed significantly higher plant height, dry matter, number of primary and secondary branches plant^{-1}at all growth stages with mustard hybrid 'DMH-1'. Similar superiority of hybrid 'DMH-1'was also exhibited in form of higher siliquae plant^{-1}, test weight, seed weight plant^{-1}and seed yield.

Singh *et al.* (2010) [39] concluded that 'NRCHB-101' with higher siliquae plant^{-1}, seeds siliqua^{-1} and test weight was proved significantly superior to 'Varuna', 'Kranti' and 'Vardan'. Similar trend was also observed in seed and stover yield which is dependent on said yield attributes.

Pachauri *et al*. (2012) [25] observed that 'Pusa Bold' with maximum number of siliquae plant^{-1}, number of seeds siliqua^{-1} and siliqua length produced maximum seed yield followed by 'Varuna', 'Rohini' and 'Kranti'. Similarly, Meena *et al.* (2013) [17] also reported varietal effect on growth parameters and 'DMH 1' outperformed 'NRCHB-506', 'PAC-37' and 'Kranti'.

Scrutiny of data recorded by Kumar *et al*. (2018) revealed distinguished effect of varieties on growth and yield attributes. However, varietal influence was observed to be non-significant with respect to harvest index.

Effect of improved cultivars on quality and nutrient uptake

Kumar *et al*. (2004) found superior quality of variety 'RB9901' over 'RH 30' and 'Laxmi' for oil yield and oil content. In another study, Kumar and Yadav (2007) reported *'Varuna'* superior to *'NDR 8501'* in terms of oil content.

Kumari (2009) [15] noted that hybrid 'DMH-1' recorded higher oil and protein yield over other varieties. Similarly, Patel *et al*. (2009) [29] noticed marked difference in oil and protein content of variety and higher values for these characters were observed in 'GM-1' as compared to remaining variety. Archana and Singh (2011) [40] concluded that the hybrid '*DMH-1*' was found superior with higher N, P and K uptake by both seed and stover at harvest as compared to *'NRCHB-506'* and *'Kranti'*. Similarly, Pachauri and Trivedi (2012) [26] recorded significant variation in N, P and S removal because of varietal difference. Meena *et al.* (2013) [17] observed significant difference among varieties with respect to oil content and oil yield. In addition, hybrid 'DMH-1' outperformed 'NRCHB-506', 'PAC-437' and 'Kranti' for total N and P uptake due higher concentration of respective nutrients in seed and stover.

Varietal response for oil content and oil yield was studied by Kumar *et al*. (2018) [12] who observed higher values of the said parameters in 'Giriraj' among varieties. Further, total uptake of N, P and S was also noted higher in 'Giriraj' superior to 'NRCHB-506' and 'Maya.

Effect of improved cultivars on profitability

Difference in growth parameters and yield attributes produced due to varietal influence bring subsequent variation in economic returns associated with the cultivation of the variety. This result is well supported by Karoria (2008) [10] who found that variety 'Pusa Bold' fetched higher net return and benefit: cost ratio followed by 'Laxmi' and 'Basundhara'. Similar varietal response for profitabilty was also studied by Patel *et al*. (2009) [29] who realized highest net returns and benefit: cost ratio with cultivation of 'GM-3' followed by 'GM-1' and 'GM-2'.

Dashora (2013) observed that 'NRCDR-2' gave highest net returns and B: C ratio (3.74) and exhibited superiority over 'Laxmi', "NRCHB-101' and 'NPJ-112' in economic terms. Similarly, Meena *et al*. (2013) [17] also noticed significant difference among mustard varieties and concluded that cultivation of hybrid 'DMH-1' was more beneficial with higher net profit and B: C ratio over other varieties.

Effect of sulphur on growth, yield attributes and productivity

Sulphur application reported to enhance cell metabolism which in turn promote meristematic activity resulting in improved growth characters such as plant height, foliage development, number of branches and dry matter accumulation. In addition, sulphur reduces soil pH which facilitate in greater nutrient availability and absorption by plants. Sulphur plays important role in oil and protein synthesis and hence, brings marked improvement in quality of seed. These functions of sulphur are well documented by the following:

Dongarkar *et al*. (2005) [3] found improvement in parameters like plant height, dry matter accumulation plant^{-1}, number of primary and secondary branches plant^{-1} with application of sulphur at 40 kg ha^{-1} lower or no dose of sulphur. Similar effect of sulphur on yield attributes was reported by Yogesh *et al*. (2009) [44] and Kapur *et al*. (2010) [9] who observed that higher level of sulphur (30 kg ha^{-1}) produced higher number of siliquae plant^{-1}, seeds sliliqua^{-1} and test weight leading to higher seed and stover yield as compared to restricted or no sulphur application.

Ray *et al*. (2014) [35] observed significant increment in different growth parameters (chlorophyll content, dry matter accumulation, number of primary and secondary branches plant^{-1}) with increasing in sulphur up to 40 kg ha^{-1}. In addition, application of sulphur also enhanced crop growth rate, relative growth rate and net assimilation rate.

Nath *et al*. (2018) [33] reported significant effect on plant height, leaf area index, dry matter accumulation plant^{-1} and number of branches plant^{-1} with increase in the levels of sulphur from 0-60 kg ha^{-1}. Further, Kumar *et al*. (2018) [12] and Rajput *et al*. (2018) [32] in separate field experiments revealed that different yield parameters as well as productivity of mustard were influenced significantly by sulphur levels and the higher length of siliqua, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, seed and stover yield were associated with application of the highest sulphur level (60 kg S ha^{-1}) but significant difference was noticed up to 45 kg ha^{-1}.

Effect of sulphur on quality and nutrient uptake

Mishra (2001) [21] observed successive increment in nutrient (N,P, K, S and Zn) content and uptake of crop with increase in level of sulphur from 0-60 kg ha^{-1} however increase was found significant only up to 40 kg S ha^{-1}.

Singh (2005) [37] observed significant improvement in oil yield, content of oil and protein of mustard seed with increase in sulphur levels from nil to 60 kg S ha^{-1} but increase in saponification, iodine and acid value was noted significant till 40 kg S ha^{-1}. Similar results were also reported by Karthikeyan and Shukla (2008) [11] who noted synergistic effect of sulphur fertilization on oil and protein content of mustard.

Jat and Mehra (2007) [7] and Zizala *et al*. (2008) [45] observed significant increase in N, P, K and S content with increase in sulphur rates up to 80 kg S ha^{-1}. While, Parmar and Parmar (2012) [28] on studying the effect of sulphur levels on quality of mustard seed found increment in palmitic, stearic, oleic and linoleic acid content with increase in sulphur level and decline in linolenic and erucic acid content with increase in sulphur level as also reported by Ray *et al*. (2015) [35]. In terms of glucosinolate content, Ray *et al*. (2015) [35] observed an increment in sinigrin and progoitrin with increased sulphur levels while gluconapin content declined with increase in S-levels.

Kabdal *et al*. (2018) concluded that application of 60 kg S ha^{-1}showed highest uptake of N, P, K, S and C uptake by both seed and stover as compared to lower levels of sulphur. Sukirtee *et al*. (2018) noticed increase in oil content and oil yield increasing sulphur application from 0-50 kg ha^{-1}. In addition, it was also reported that increasing levels of sulphur also brought significant increment in N, P, K and S content in mustard seed up to the maximum sulphur level of 50 kg S ha^{-1}.

Effect of sulphur on profitability of mustard

Improvement in growth, yield attributes and productivity attained with higher sulphur application ultimately results in higher gross as well as net returns as also evident from following study:

Kumar *et al*. (2009) [15] recorded maximum net returns and benefit: cost ratio with 45 kg S ha^{-1}, followed by 30 and 15 kg S ha^{-1}. Similar results were also reported by Piri *et al*. (2011) [31] who also noticed that 45 kg S ha^{-1} gave the maximum net return and benefit: cost ratio followed by 30 kg S ha^{-1}. In both the studies, no sulphur application recorded least gross return, net return and benefit: cost ratio.

Significant variation in gross and net returns was also observed by Ray *et al*. (2014) due to sulphur fertilization in which highest gross and net income with benefit: cost ratio was noticed with 30 kg S ha^{-1}.

Economics of mustard cultivation was also evaluated by Kabdal *et al*. (2018) [8] who found increase in returns with increasing levels of sulphur and application of sulphur at the rate of 60 kg ha^{-1} fetched maximum gross and net returns. Increase in sulphur fertilization though add to cost of cultivation but the consequent returns achieved with sulphur outnumber the treatment cost and 60 kg S ha^{-1} fetched highest gross returns and benefit: cost ratio (Kumar *et al*., 2018) [12]. Similar results were also reported by Sahu *et al*. (2018) [36].

Conclusion

Thus, it is evident that manipulation in irrigation regimes, selected variety and sulphur nutrition cause significant improvement in growth characteristics of mustard which further results in better yield contributing characters and productivity that can address the growing demand of vegetable oil as well as can bring down import expenditure on vegetable oil substantially. In addition, optimum use of the concerned inputs also improves the quality of seed and fetches higher economic value to the farmers improving their living standards markedly and thus increasing its share in gross national product.

References

1. Dashora L N Effect of sulphur on productivity of Indian mustard [(*Brassica juncea* (L.) Czern and Coss.)] Genotypes (Doctoral dissertation, MPUAT, Udaipur). 2013.
2. DOAC. Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Department of Agriculture and Cooperation. Ministry of Agriculture, Government of India. 2017.
3. Dongarkar KP, Pawar WS, Khawale VS, Khutate NG, Gudadhe NN. Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea* L.). Journal of Soils and Crops. 2005; 15(1):163-167.
4. Ghanbahadur MR. Response of Mustard Genotypes to Sowing Dates and Water Management (Doctoral dissertation, Dr. Panjabrao Deshmukh Krishi Vidyapeeth; Akola), 2002.
5. Ghanbahadur MR and Lanjewar BK. Influence of sowing dates, irrigation levels and mulching on nutrient uptake and yield of mustard cv. ACN-9. Journal of Soils and Crops. 2006; 16(1):158-164.
6. Jat AL, Rathore BS, Desai AG, Shah SK. Production potential, water productivity and economic feasibility of Indian mustard (*Brassica juncea*) under deficit and adequate irrigation scheduling with hydrogel. Indian Journal of Agricultural Sciences. 2018; 88(2):212-215.
7. Jat JR, Mehra RK. Effect of sulphur and zinc on yield, macronutrient content in and uptake by mustard on Haplustepts. Journal of the Indian Society of Soil Science. 2007; 55(2):190-195.
8. Kabdal P, Saxena SC, Mahapatra BS. Nitrogen and sulphur fertilization on yield and nutrient-uptake pattern of Indian mustard (Brassica juncea) under Mollisols of Uttarakhand. AGRONOMY. 2018; 201.
9. Kapur LT, Patel AR, Thakor RF. Yield attributes and yield of mustard (*Brassica juncea* L. Czern and Coss) as affected by sulphur levels. Asian Journal of Soil Science. 2010; 5(1):216-217.
10. Karoria BS. Effect of varieties and irrigation schedules on yield of mustard (*Brassica juncea* L.) (Doctoral dissertation, JNKVV, Jabalpur). 2008.
11. Karthikeyan K, Shukla LM. Effect of boron–sulphur interaction on their uptake and quality parameters of mustard (*Brassica juncea* L.) and sunflower (Helianthus annuus L.). Journal of the Indian Society of Soil Science. 2008; 56(2):225-230.
12. Kumar D, Singh JK, Nanda G. Effect of levels and sources of sulphur on growth, yield, nutrient removal and relative economics of Indian mustard [*Brassica juncea* (L.)] varieties under irrigated conditions. SKUAST Journal of Research. 2018; 20(1):53-57.
13. Kumawat PD. Response of Indian Mustard (*Brassica juncea* (L.) Czern. and Coss.) to Seed Treatment and Foliar Spray of Sulphuric Acid under Varying Levels of Irrigation (Doctoral dissertation, Ph. D. thesis, Rajasthan Agricultural University, Bikaner), 2004.
14. Kumar S, Verma SK, Singh TK, Singh S. Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (*Brassica juncea*) under rainfed condition. Indian Journal of Agricultural Sciences. 2009; 79(8):648.
15. Kumari A. Evaluation of hybrid varieties of mustard (*Brassica juncea* L.) under different sowing time and spacing (Doctoral dissertation, GB Pant University of Agriculture and Technology, Pantnagar-263145 (Uttarakhand). 2009.
16. Kumari A, Singh RP. Productivity, nutrient uptake and economics of mustard hybrid (*Brassica juncea*) under different planting time and row spacing. Indian Journal of Agronomy. 2012; 57(1):61-67.
17. Meena DS, Meena VR, Meena AK. Fertilizer management studies on growth and productivity of hybrid Indian mustard *Brassica juncea* (L.). Journal of Oilseed Brassica. 2013; 4(1):39-42.
18. Meena R. Response of mustard (*Brassica juncea* L.) to irrigation and potash fertilization (Doctoral dissertation, Anand Agricultural University, Anand). 2011.
19. Meena RK. Effect of Irrigation Levels and Agrochemicals on Productivity of Mustard [*Brassica juncea* (L.) Czern. & Coss] (Doctoral dissertation, MPUAT, Udaipur). 2010.
20. Mishra SK. Effect of sulphur and zinc on yield, uptake of nutrients and quality of mustard. Annals of Plant and Soil Research. 2001; 3(2):206-213.
21. Morris RJ. Sulphur in agriculture: International Perspective. In: Proc. TSI-FAI-IFA Symposium cum Workshop on Sulphur in Balanced Fertilization, 1-7 (Eds. RK, Tewatia RS, Choudhary and S. P. Kalwe).New Delhi: The Fertilizer Association of India. 2007.
22. Nagdive SJ, Bhalerao PD, Dongarwar UR, Goud VV. Effect of irrigation and nutrient management on yield, quality and uptake of nutrients by mustard (*Brassica juncea* L.). Journal of Soils and Crops. 2007; 17(1):128-132.
23. Nath S, Kannaujiya SK, Kumar S, Sonkar SP, Gautam AD, Singh A. Effect of Sulphur Fertilization on Yield, Sulphur Uptake and Oil Content in Indian Mustard under Sandy Loam Soil of Eastern Uttar Pradesh. Scientists joined as life member of society of Krishi Vigyan. 2018; 81.

24. Negi A, Pareek N, Raverkar KP, Chandra R. Effect of Two Sulphur Sources on Growth, Yield and Nutrient Use Efficiency of Brassica. International Journal of Science, Environment and Technology. 2017; 6:236-247.
25. Pachauri RK, Trivedi SK. Effect of sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea*) genotypes. Annals of Agricultural Research. 2012; 33(3).
26. Pachauri RK, Trivedi SK, Yogendra K. Effect of sulphur levels on growth, yield and quality of Indian mustard genotypes and their economics. Journal of Soils and Crops. 2012; 22(2):258-263.
27. Parmar BS, Patel MM, Patel JC, Patel DM, Patel GN. Enhance mustard [*Brassica juncea* (L.) Czern and Coss] productivity through sprinkler irrigation under north Gujarat conditions. Research on Crops. 2016; 17(1):63-67.
28. Parmar JK, Parmar RM. Effect of nitrogen and sulphur on quality characteristics and accumulation of some fatty acids in mustard seeds grown under loamy sand soil of North Gujarat. Asian Journal of Soil Science. 2012; 7(2): 167-171.
29. Patel GM, Patel BT, Dodia IN, Bhatt VK, Bhatt RK. Effect of sources and levels of sulphur on yield, quality and nutrient uptake of mustard (*Brassica juncea* L.) varieties in loamy sand soil. Journal of Soils and Crops. 2009; 19(1):30-35.
30. Piri I, Sharma SN. Physiological analysis of growth and yield of Indian mustard as affected by irrigation and sulphur. Indian Journal of Plant Physiology. 2006; 11(3): 253.
31. Piri I, Nik MM, Tavassoli A, Rastegaripour F, Babaeian M. Effect of irrigation frequency and application levels of sulphur fertilizer on water use efficiency and yield of Indian mustard (Brassica juncea). African Journal of Biotechnology. 2011; 10(55):11459-11467.
32. Rajput RK, Singh S, Varma J, Rajput P, Singh M, Nath S. Effect of different levels of nitrogen and sulphur on growth and yield of Indian mustard (*Brassica juncea* (L.) Czern and Coss.) in salt affected soil. Journal of Pharmacognosy and Phytochemistry. 2018; 7(1):1053-1055.
33. Rathore SS, Shekhawat K, Dass A, Premi OP, Rathore, BS, Singh VK. Deficit Irrigation Scheduling and Superabsorbent Polymer‐ Hydrogel Enhance Seed Yield, Water Productivity and Economics of Indian Mustard Under Semi‐ Arid Ecologies. Irrigation and Drainage. 2019.
34. Ray K, Pal AK, Banerjee H, Phonglosa A. Correlation and path analysis studies for growth and yield contributing traits in Indian mustard (*Brassica juncea* L.). International Journal of Bio-resource and Stress Management. 2014; 5(2):200-206.
35. Ray K, Sengupta K, Pal AK, Banerjee H. Effects of sulphur fertilization on yield, S uptake and quality of Indian mustard under varied irrigation regimes. Plant, Soil and Environment. 2015; 61(1):6-10.
36. Sahu DK, Swaroop N, Prasad D, Kanwar DS, Singh P. Effect of Different Doses of Sulphur and Zinc with NPK on Different Growth Parameters and Yield Attribute of Yellow Mustard (*Brassica campestris* L.) cv. Sunanda. International Journal of Current Microbioloy and Applied Sciences. 2018; 7(3):1014-1022.
37. Singh SC. Response of Indian mustard *Brassica juncea* L to sources and levels of sulphur, 2005.
38. Singh P, Kumar M, Maurya CL, Swarnkar SK. Effect of S and Zn nutrients on growth, seed yield and quality of Indian mustard [*Brassica juncea* (L.) Czern and Coss.] Varieties. Progressive Agriculture. 2007; 7(1and2):124-127.
39. Singh RK, Singh Y, Singh AK, Kumar R, Singh VK. Productivity and economics of mustard (Brassica juncea) varieties as influenced by different fertility levels under late sown condition. Indian Journal of Soil Conservation. 2010; 38(2):121-124.
40. Singh SP, Pal MS. Effect of integrated nutrient management on productivity, quality, nutrient uptake and economics of mustard (*Brassica juncea*). Indian Journal of Agronomy. 2011; 56:381-387.
41. Singh SM, Shukla A, Chaudhary S, Bhushan C, Negi MS, Mahapatra BS. Influence of irrigation scheduling and hydrogel application on growth and yield of Indian mustard (*Brassica juncea*). Indian Journal of Agronomy. 2018; 63(2):246-249.
42. Sukirtee, Singh YV, Ranjan KR, Menka K, Bharteey PK. Interaction effect of nitrogen and sulphur on yield, oil and nutrient content of mustard (*Brassica juncea* L.) in an inceptisol. International Journal of Chemical Studies. 2018; 6(6):1234-1238.
43. Yadav RD. Effect of mulching and sulphur on mustard [*Brassica juncea* (L.) Czernj and Cosson] under varying levels of irrigation (Doctoral dissertation, Ph. D. (Ag.) Thesis, Rajasthan Agriculture University, Bikaner). 2005.
44. Yogesh K, Dawson J, Kishanrao ZK, Dixit PM, Rahul K. Effect of nitrogen, phosphorus and sulphur fertilization on growth and yield of mustard (*Brassica juncea* Coss). International Journal of Agricultural Sciences. 2009; 5(2): 396-398.
45. Zizala VJ, Jadav NB, Gorfad PS. Effect of sulphur and zinc on yield, quality and its concentration on mustard. Asian Journal of Soil Science. 2008; 3(1):173-177.