Effect of soil fertigation on oil content and oil quality of oilseed crops

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Oil and fats are important parts of the human diet and more than 90% of the world’s production from vegetables, animals and marine sources is used as food or as an ingredient in food products. Edible vegetable oils are food stuffs which are composed primarily of glycerides of fatty acids being obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, of unsaponifiable constituents and of free fatty acids naturally present in the fat or oil (CODEX STAN 210-1999).

Oilseed crops have been the backbone of agricultural economy of India from time immemorial. Edible oil seeds crops such as mustard, groundnut, sunflower, safflower, sesame, niger, soybean and non-edible like linseed and castor are grown in various parts of India. In addition to oilseed crops, secondary sources of edible oils like rice bran, cotton seed, coconut, palm oil and tree borne oilseeds are also popular in India. In oil seeds quality criteria are fatty acid composition (Table-1), tocopherols, phenolic compounds of the seed oil and the intended use of the oil. When grown under widely different conditions, seeds frequently show such marked changes in quality parameters that also effect there commercial value.

**Table: 1Fatty acid composition and ratio of saturated, monounsaturated and polyunsaturated fatty acids in various oils.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Oil  | 8:0 (CL) | 10:0 (C) | 12:0 (L) | 14:0 (M) | 16:0 (P) | 16:1 (PL) | 18:0 (S) | 18:1 (OL) | 18:2 (LA) | 18:3 (ALA) | 20:0 (AA) | 20:1 (G) | 22:1 (E) | S | MUFA | PUFA |
|  Coconut  | 8.0 | 6.4 | 48.5 | 17.6 | 8.4 |   | 2.5 | 6.5 | 1.5 |   | 0.1 |   |   | 91.4 | 6.5 | 1.5 |
|  Palm kernel  | 3.9 | 4.0 | 49.6 | 16.0 | 8.0 |   | 2.4 | 13.7 | 2.0 |   | 0.1 |   |   | 83.9 | 13.7 | 2 |
|  Palm  |   |   |   |   | 45.1 | 0.1 | 4.7 | 38.8 | 9.4 | 0.3 | 0.2 |   |   | 49.8 | 38.9 | 9.7 |
|  Olive  |   |   |   |   | 13.7 | 1.2 | 2.5 | 71.1 | 10.0 | 0.6 | 0.9 |   |   | 16.2 | 72.3 | 10.6 |
|  Groundnut  |   |   |   | 0.1 | 11.6 | 0.2 | 3.1 | 46.5 | 31.4 |  | 1.5 | 1.4 |   | 14.8 | 48.1 | 31.4 |
|  Rice bran  | 0.1 | 0.1 | 0.4 | 0.5 | 16.4 | 0.3 | 2.1 | 43.8 | 34.0 | 1.2 | 0.5 |   |   | 19.6 | 44.1 | 35.1 |
|  Mustard  |   |   |   | 1.4 | 3.8 | 0.2 | 1.1 | 11.6 | 15.3 | 5.9 | - | 6.2 | 41.1  | 6.3 | 59.1 | 21.2 |
|  Corn  |   |   |   |   | 12.2 | 0.1 | 2.2 | 27.5 | 57.0 | 0.9 | 0.1 |   |   | 14.4 | 27.6 | 57.9 |
|  Cottonseed  |   |   |   | 0.9 | 24.7 | 0.7 | 2.3 | 17.6 | 53.3 | 0.3 | 0.1 |   |   | 27.9 | 18.3 | 53.6 |
|  Sunflower  |   |   | 0.5 | 0.2 | 6.8 | 0.1 | 4.7 | 18.6 | 68.2 | 0.5 | 0.4 |   |   | 12.2 | 18.7 | 68.7 |
|  Safflower  |   |   |   | 0.1 | 6.5 |   | 2.4 | 13.1 | 77.7 |   | 0.2 |   |   | 9 | 13.1 | 77.7 |
|  Soybean  |   |   |   | 0.1 | 11.0 | 0.1 | 4.0 | 23.4 | 53.2 | 7.8 | 0.3 |   |   | 15.1 | 23.5 | 61 |
|  Linseed  |   |   |   |   | 4.8 |   | 4.7 | 19.9 | 15.9 | 52.7 |   |   |   | 9.5 | 19.9 | 68.6 |
|  Sesame  |   |   |   |   | 9.9 | 0.3 | 5.2 | 41.2 | 43.1 | 0.5 |   |   |   | 15.1 | 41.5 | 43.5 |

Almost 72 % of the total oilseeds area is confined to rainfed farming, cultivated mostly by small and marginal farmers. Seven of the sixteen essential plant nutrients are referred to as micronutrients. Micronutrients are essential for plant growth, but plants require relatively in smaller quantity includes iron (Fe),manganese (Mn), zinc (Zn), boron (B), copper (Cu), molybdenum (Mo) chlorine (Cl ). In oilseeds the micronutrients play a major role in translocation of photosynthates, increasing seed setting percentage, essential for translocation of sugar, germination of pollen grains, stigma receptivity, amino acid and protein synthesis which ultimately increase the productivity of oilseed crops .

Plant growth involves the interaction of soil and plant properties. Maximum plant growth and realization of yield potential depends on the soil characteristics covering the biological, chemical and physical conditions necessary for the root system to maximize the plants required absorption of nutrients and water and to enable the biochemical reactions that occur in the root.

**Mustard**

Ahmad et al. (2007) used a dose of 0, 10, 20, and 30 kg.ha−1S in mustard crop and found that oil content was significantly increased with the increasing doses of sulphur to 20 kg.ha−1. The higher dose of sulphur had no significant effect on the oil content. Conversely, Subhani et al. (2003) reports, that the oil content is directly proportional to the doses of sulphur in mustard. A beneficial effect of 60 kg.ha−1 S, on the oil content was also reported by Malarz et al. 2011). On the contrary, Walker and Booth (2003) and Varényiová (2007) state that in contrast to the yield, the oil content is not dependent on the dose of sulphur in mustard. Protein content is in negative correlation with oil content, so the effect of sulphur on the oil content of oil seeds is ambiguous. Lääniste et al. (2004) carried out field trials, to investigate the effect of microfertilisers on the seed oil content of rape cultivar ‘Mascot’. Analyses of test results revealed that different microelements influenced the oil content of rape seeds. The mixture of microfertilisers in the trial had a positive effect on seed oil content. Foliar application of manganese and molybdenum increased the oil content in the seeds more than one percent.

**Soybean**

Soybean has a very good adaptability towards a wide range of soils and climate. Soybean requires an optimum temperature of 26oC to 30oC.The best type of soil is sandy loam having good organic manure content. Soils with a normal pH of 7 and a fair degree of water retention capacity are better suited for its cultivation. Soybean responds well to both organic and inorganic fertilizers. Few authors studied effect of soybean cv ‘Macs 124’ quality parameters like oil content and protein content with 50 kg N/ha or urea, FYM, compost, vermicompost and found that improvement in oil content and protein with 50% each of urea and FYM, Bachham and Sabale (1996). Soybean oil content and protein will be majorly influenced due to levels of sulphur and boron levels in soils. The highest seed yield, oil, protein content and net return were obtained at 50 kg S application/ha through gypsum (Sharma, 1996). The better availability of desired and required nutrients in the root zone resulting from its solubilisation caused by the organic acids produced from the decomposition of organic manures. Secondly, the availability of nitrogen, phosphorus, potassium and organic carbon enhanced the integration of inorganic fertilizers, FYM and biofertilizers which enhanced the use of organic and inorganic nutrient sources for higher production and stable soil health and results in improvement of soybean oil content and quality (Singh and Rai, 2004: Shivkumar and Ahlawat, 2008).

Soil pH is negatively influences the yield and quality of soybean. Molybdenum is directly involves in crop metabolism and necessary trace elements for crop growth. Element Se is an important for soil health and indirectly influence crop growth. Nitrogen not only plays a major role in crop growth but also for improvement in crop protein, nucleic acid and nuclear protein as well as the basis of genetic material. Potassium promotesroot and activation of plant endoenzymes, thereby enhancing plant photosynthate. The contents of Mo, Se, K, N and soil organic matter and cation exchange coefficient are positive,while the contents of B, Hg, MgO, Cd and the pH value are negative on soybean yield. Whereas B, Mo, Se, K and N contents and the cation exchange coefficient have a positive effect on soybean quality, and the Hg, Mg and Cd contents have a negative effect on soybean quality. The element contents of Mo, Se, K and N, the soil organic matter content and the cation exchange coefficient showed a positive effect both on soybean production and soybean quality (Ming Gao and Shiwei Li, 2017).

**Groundnut**

Groundnut requires considerable amounts of nutrients for high yields, however, responses to applied fertilizers have been observed to be very erratic, justifying the name of “the unpredictable legume”. It has often been accepted that groundnut has the ability to utilize soil nutrients that are relatively unavailable to other crops, and can therefore make good use of residual fertility. The most critical element in the production of groundnuts is calcium, and in many regions of the world, it is a major limiting factor to groundnut production. The developing pods require adequate Ca in the surrounding soil for proper pod development and production of high quality seed. Magnesium deficiency rarely limits plant growth, however, its necessity for groundnut stems from its role as a carrier of phosphorus in oil formation, and its effect on seed viability.

Oil content increased up to the application of 60 kg N and 60 kg K2O ha-1. Pod and oil yield increased with N and K2O up to 40 and 45 kg ha-1, respectively (Patra et al. 1995). The seed protein increase was observed with increasing nitrogen levels but resulted in decrease of oil content (Kandil et al. 2007). Barik and Mukherjee (1995) observed higher oil content of 49.33% in groundnut with the optimized application of 40 kg N ha-1 during summer season. The change in nitrogen levels did not varies fatty acid content steadily but variation in some fatty acid was observed i.e., palmitic acid (9.86 to 10.31%), stearic acid (4.55 to 5.06%), oleic acid (52.00 to 53.31%), linoleic acid (21.77 to 23.14%), linolenic acid (0.046 to 0.054%), aracadic acid (1.75 to 2.23%), and behenic acid (2.08 to 2.60%) (Boydak et al. 2010). Influence due to phosphorus application most reports stated that 50-60 kg P2O5 ha-1augmented the oil content and protein content (Dimree and Dwivedi1994). Even sulphur content @ 45 kg ha-1 increases oil content and protein content (Dimree and Dwivedi1994). Higher oil content (48.3 %) was achieved with fertilizer does of 40 kg N, 17.5 kg P2O5 and 20 kg K2O ha-1 studied by Devi and Reddy (1991).

**Safflower**

Mohsennia and Jalilian, 2012 studied the effect of 100 kg.ha-1 Urea, Humix as organic fertilizer, Biofertilizers (Nitroxin, Biosoulphour, integrated fertilize treatments: (Urea + Humix + Nitroxin), (Urea + Humix + Biosoulphour), and control on the oil content and quality parameters of safflower. There was an increase in protein percentage approximately 7.4% with Biosoulphour application under irrigation disruption at reproductive growth stage compared to the application of organic fertilizer under well-irrigation condition. Oil yield was significantly affected by fertilization treatment. Integrated fertilize treatments (Urea + Humix + Biosoulphour) and control fertilization treatments produced the maximum (657.2 kg ha-1) and minimum (455.3 kg ha-1) oil yield. The highest levels of oleic acid (14.36%) and linoleic acid (75.40%) were obtained from control and biosoulphoure treatments, respectively. Whereas, the lowest levels of oleic acid (13.33%) and linoleic (74.15%) were observed in biosoulphoure and control treatments, respectively. control plants and plants receiving T1 fertilization treatments produced the highest levels of palmitic acid (6.38%) and stearic acid (2.47%), respectively. . Singh and Singh (2013) noticed an increase in oil content (33.5%) and protein content (16.5%) of safflower with increase in N rate upto 80 kg ha-1 on sandy clay loam soils of Agriculture Research Farm, BHU, Uttar Pradesh. Application of nitrogen @ 156 kg ha-1 recorded significantly higher seed oil percentage (23.75%) compared to 0, 84 and 120 kg N ha-1 and highest seed protein percentage (14.4%) was recorded in 120 kg N ha-1 on par with 156 kg N ha-1 in safflower (Taleshi et al., 2012). Bitarafan et al. (2011) reported that maximum oil content (33.46 %) was obtained by applying 100 kg N ha-1 compared to 0 kg N ha-1 (30.41%) in safflower on clay loam soils of Iran. Sudhir Singh Bhadauria (1999) observed that, in safflower higher oil content (32.96 %) and protein content (20.23%) was recorded with 60 kg N ha-1 compared to control on sandy loam soils of Gwalior. Reddy et al. (1994) reported a slight decrease (0.19 %) in safflower seed oil content and increase in protein content with increase in the nitrogen level upto 60 kg ha-1 on sandy loam soil of Rajendranagar (Hyderabad). Field trials conducted in safflower at Faizabad revealed that there was significant decrease in oil content with increasing dose of N upto 60 kg ha-1 while the highest oil content (32.47 %) was recorded in control (without nitrogen) followed by 15 kg N ha-1 (31.43 %) and lowest (27.07 %) by 60 kg N ha-1 on silty loam soil (Singh et al., 1992). Zaman and Das (1991) reported that N at 40, 80 and 120 kg ha-1 in safflower increased the oil content by 1.6, 2.8 and 3.9 percent respectively over no nitrogen (control) on sandy loam soil of West Bengal. Katole and Meena (1988) observed that there was a decrease in oil content with increase in dose of nitrogen, highest oil content (28.4%) in control and least (24.7%) in 60 kg N ha-1 in safflower on clay loam soils of Udaipur, Rajasthan. In sandy loam soils at West Bengal, Zaman (1988) recorded an increase in safflower oil content (29.64 %) with increase in N rate upto 60 kg ha-1 and significant decrease beyond 60 kg ha-1 upto 120 kg N ha-1. Oil and protein content of safflower increased significantly upto 40 kg S ha-1, although there was improvement in the oil and protein content with subsequent increase in sulphur levels upto 60 kg S ha-1 (Singh and Singh, 2013).

**Sunflower**

Nasim et al. (2012) studied the effect of nitrogen on yield and oil quality of sunflower hybrids under sub humid conditions of Pakistan and reported that maximum grin oil content (46.2%) were produced with 60 kg N/ha followed by 120 kg N/ha (46.1%). The minimum grin oil content (40.6%) observed with 240 kg N/ha. This result shows that an increase in N fertilizer increases the grain yield but reduces the grin oil content (Malik et al. 2001). Increasing N rates reduced seed oil percentages but increased seed yields and consequently increased oil yield per unit area (Zheljazkov et al., 2008; 2009). Ali and Ullah (2012) also reported that oil content in achene decreased with higher N levels. Munir et al. (2007) and Nasim et al. (2011) also observed decreases in achene oil percentages with increased N application. Phosphorus fertilizer had no significant effect on chemical composition; this associated with decrease on reproductive growth stage and decreased the seed oil content. Similar results were obtained by Maheswarappa et al., (1985) for oil content and protein content (Singh and Singh, 1977). Several researchers reported that, the oil content is reduced by N application (Khokani et al., 1993; Mojiri and Arzani, 2003). Nitrogen fertilizer had no significant effect on protein content (Ali et al. 2014).

**Castor**

Hussein et al. 2013 reported that the highest values for oil % and consequently oil yield kg/faddan (48.03% and 254.73 t/faddan, respectively) were recorded by 3/4 recommended N fertilizer + 5 m3/ faddan, chicken manure + Cerealine inoculants. Meanwhile, the highest contents of crude protein, crude fiber and ash were recorded by Recommended N + Cerealine inoculants. Patel *et al*. 2010 opined that *Rabi* castor grown on vertic ustrochrepts of South Gujarat registered significantly higher oil yield due to application of 100 % RDN (80kg N ha ) + bio-compost (5 t ha ) over the 100 % RDN. Similarly, Kumar and Kanjana, 2009 noticed that application of FYM (12.5 t ha ) + *Azospirillum* (2 kg ha ) + Phosphobacteria (2 kg ha ) to castor plants under irrigated conditions recorded significantly higher oil yield. However, Baby and Reddy 1998 reported that different nitrogen levels do not influence the oil content in castor. Contrary to the above, Rao *et al*. 1998 reported that oil content in the rainfed castor decreased with increase in N application from 0 to 120 kg ha.

**Sesame**

Murmu et al. 2015 found that the quality parameters of sesame such as crude protein, oil content and soluble sugar improved under different sulphur fertilizer treatments, maximum being in RD with SSP. Sulphur fertilizer application, therefore exhibited potential in improving crop yield and quality of sesame. Raja et al., 2007 demonstrated that the optimum level of S can be fixed as 48 kg ha-1 for better growth, yield and quality of sesame crop. Mathew et al., 2013 reported that sulphur and boron has a synergistic effect on the yield and yield contributers of the sesame andalso has the positive effect on the improving the quality attributes. Thakur et al. 1998 reported significant increase in seed, oil and protein yield of sesame with the application of fertilizer dose upto 45 kg N+30 kg P2O5/ ha at Raigarh (Chhatishgarh).

**Linseed**

Berti et al. (2009) observed that there was no effect of N, P, K and their interactions on oleic, linoleic, and alpha-linolenic acids. Nitrogen rate increased oil content. However, oil composition was not affected by N, P, and K rates, or their interactions. Dybing (1965) reported a decrease in alphalinolenic acid as N rates were increased in flaxseed in a greenhouse study with controlled NO3 solutions from 14 to 224 mg L-1. Tomar and Tomar (2013) stated that the maximum oil in linseed (42.60 %) was produced when 20 kg S ha-1 applied through ammonium sulphate. Very recently Dohat et al. (2017) reported that the oil content was recorded higher with application of nitrogen @ 30 kg N ha-1 in linseed. Similar type of results also obtained by Rafey et al. (1988), Chourasia et al. (1992), Vashishtha (1993) and Singh et al. (1997).

**Niger**

Dhange et al. (2009) studied the effect of phosphorus fertilizer on seed yield and oil content and reported that oil percentage in grain was significantly influenced by phosphorus levels. Application of phosphorus 60 kg P2O5 ha-1 was significantly superior over P0, P1 and P2. Results are in confirmation with the studies of Kachapur et al. (1980). Mamatha et al. 1994 pointed that the oil content in niger seeds decreased with increased nitrogen application, while it increased with phosphorus and sulphur application, but the seed and oil yield was maximum with application of 40 kg N + 80 kg P2O5 at Bangalore (Kamataka). Nandini Devi et al 2000 emphasized that application of 60:30:30:40- N:P:K:S kg/ha proved to be the best fertilizer dose for increasing the grain and oil yields of niger in the lateritic belts of West Bengal. However, Talukdar et al. 2016 noticed that varying sources or level of nitrogenous nutrients had no impact on oil content in seeds of Niger. Tadayyon et al. 2016 showed that foliar application of humic acid, zinc, and iron resulted in a significant increase in all quality parameters.

**References:**

1. Ahmad, G., Jan, A., Arif, M., Jan, M. T. and Khattak, R. A. 2007. Influence of nitrogen and sulfur fertilization on quality of canola (*Brassica napus* L.) under rainfed conditions. Journal of Zhejiang University. Science. 8(10): 731–737
2. Ali, A. and Ullah, S. 2012. Effect of nitrogen on achene protein, oil, fatty acid profile, and yield of sunflower hybrids. Chilean J. Agric. Res., 72(4): 564-567.
3. Ali, A.B., Altayeb, O.A., Alhadi, M. and Shuang- En, Y. 2014. Effect of different levels nitrogen and phosphorus fertilization on yield and chemical composition hybrid sunflower grown under irrigated condition. J. Env. Agric. Sci. 1: 1-7.
4. Baby, A. and T. B. Reddy, 1998. Integrated nutrient management in rainfed castor. J. Oilseeds Res., 15(1): 115-117
5. Bachham, P. R. and Sabale, R. N. 1996. Effect of different sources of N on growth parameters, yield and quality of Soybean. Journal of Maharashtra Agricultural University, 21(2):224-247.
6. Barik, A. K. and Mukherjee, A. K., 1995, Effect of cropping system and nitrogen on the yield, oil content and nodulation in summer groundnut. Indian J. Agron., 43 (1): 27-32
7. Berti, M., Fischer, S., Wilckens, R. and Hevia, F. 2009. Flaxseed response to N, P, and K fertilization in south central Chile. Chilean J. Agric. Res., 69(2): 145-153.
8. Bitarafan, Z., Shirani-Rad, A.H. and Delkhosh, B. 2011. Nitrogen rates and sowing date effect on yield and oil content of spring safflower. Internl. J. of Science and Advanced Tech., 1(6): 25-30.
9. Boydak. E., DavutKaraaslan and HuseyinTurkoglu., 2010, The effect of different nitrogen and irrigation levels on fatty acid composition of peanut oils. Turkish J. Field Crops, 15 (1): 29-33.
10. Chourasia, S.K., Namdeo, K.N. and Chourasia, S.C. 1992. Effect of nitrogen, sulphur and boron on growth, yield and quality of linseed. Indian J. Agronomy, 37(3): 496- 499.
11. Devi, T. C. C. and Reddy, M. G. R., 1991, Effect of gypsum, N and P fertilizer on groundnut, Indian J. Agron., 36 (2) : 265-266.
12. Dimree, S. and Dwivedi, K. N., 1994, Response of sulphur and phosphorus on groundnut. J. Oilseeds Res., 11: 193-195
13. Dohat, M.P., Patel, R.A., Desai, C.K. and Patel. H.K. 2017. Quality of linseed (*Linum usitatissimum* L.) influenced by irrigation and level of nitrogen. J. Pharmacognosy and Phytochemistry, 6(4): 1943-1944.
14. Dybing, C.D. 1965. Influence of nitrogen level on flax growth and oil production in varied environments. Crop Sci., 5: 491-494.
15. In: National Seminar on “Oilseed and Oils- Research and Development Needs in the Millennium" Extended Summaries, pp 184-185Hussein, M.M., Tawfik, M.M. El Habbasha S.F. and Mekki, B.B. 2013. Prospect of Bacterial Inoculants and Organic Fertilizers for Improving Growth, Productivity and Quality of Castor Bean (*Ricinus communis* L.) Plants in Newly Reclaimed Sandy Soils**.** World Journal of Agricultural Sciences 9 (6): 421-428
16. Kachapur, M.D., Radder, G.D. and Biradar, B.N. 1980. Quality studies in niger genotypes in relation to spacing and fertility levels. Oilseeds J., 11: 38-41.
17. Kandil, A. A., El-Haleem, A. K. A., Khalafallah, M. A., El-Habbasha, S. F., Abu-Hagaza, N. S. and Behairy, T. G., 2007, Effect of nitrogen levels and some bio-fertilizers on dry matter, yield and yield attributes of groundnut. Bulletin of the National Research Centre (Cairo), 32 (3): 341-359.
18. Katole, N.S and Meena, G. P. 1988. Effect of row spacing, nitrogen and irrigation on seed yield, oil content and water requirement of safflower. Indian J. of Agronomy, 33(3): 339-341.
19. Khokani M.G., Ahlawat R.P.S. and Trivedi, S.J. 1993. Effect of nitrogen and phosphorus on growth and yield of sunflower (*Helianthus annuus* L.). Indian J. Agron., 38: 507-509.
20. Kumar, N.S. and D. Kanjana, 2009. Influence of integrated nutrient management practices on yield attributes, seed yield, oil yield and nutrient uptake of castor under irrigated conditions. Indian Journal of Agricultural Research, 43(3): 200-205
21. Lääniste, P., Jõudu J. and Eremeev V. 2004. Oil content of spring oilseed rape seeds according to fertilisation. Agro. Res. 2(1), 83–86
22. Maheswarappa, K.P., Shambolingappa, K.G., Bajavaraju, G.V. and Kumar, D. S. R. 1985. Role of nitrogen and phosphorous fertilization on test weight, protein, oil and germination of Bsh-1 Sunflower. Seeds Farms, 11:1, 23-25.
23. Malarz, W., Kozak, M. and Kotecki, A. 2011. The effect of spring fertilization with different sulphur fertilizers on the growth and morphological features of winter oilseed rape ES Saphir cultivar. RośtlinyOleiste–Oilseed Crops, 32: 107–115
24. Malik, M.A., Shah, S.H., Mahmood, Mahmood, S. and Cheema, M.A. 2001. Effect of various planting geometries on the growth, seed yield and oil contents of new sunflower hybrid (SF-187). Inter. J. Agric. Biol., 3(1): 55-56.
25. Mamatha, B. R., Shivaraj, B. and Gowda, A. 1994. Effect of N, P, K and S on seed and oil yield on niger. Current Research, 3(9): 108-110
26. Mathew A., George S and Indira M 2013. Effect of sulphur and boron on the performance of sesame in Ontukara sandy soils of Kerala, INDIA. Indian J. Agric. Res. 47 (3) 214-219
27. Ming Gao and Shiwei Li. Relationship between soybean yield/quality and soil quality in a major soybeanproducingarea based on a 2D-QSAR model. AIP Conference Proceedings 1839, 020071
28. Mohsennia and Jalilian, 2012, Response of safflower seed quality characteristics to different soil fertility systems and irrigation disruption. Int. Research J. App. Basic Sci. Vol., 3 (5), 968-976, 2012
29. Mojiri, A. and Arzani, A. 2003. Effects of nitrogen rate and plant density on yield and yield components of sunflower. J. Sci. Tech. Agric. Natur. Res., 7: 115-125.
30. Munir, M.A., Malik, M.A. and Saleem, M.F. 2007. Impact of integration of crop manuring and nitrogen application on growth, yield and quality of spring planted sunflower (*Helianthus annuus* L.) Pakistan J. Bot., 39: 441-449.
31. Murmu, S., Murmu, K., and Satapathy, M. 2015. Effect of sulphur fertilization on growth, yield and quality of sesame (sesamum indicum l.) in mid central zone of odisha. Int. J. Bio-res. Env. Agril. Sci. 1(1): 5-12
32. Nandini Devi K., Ghosh, R.K., Bhowmick, M.K. and Sounda, G. 2000. Effect of different levels on NPK and S on growth, yield and oil content of niger in Alfisols of West Bengal.
33. Nasim, W., Ahmad, A., Wajid, A., Akhtar, J. and Muhammad, D. 2011. Nitrogen effects on growth and development of sunflower hybrids under agro-climatic conditions of Multan. Pakistan J. Bot., 43: 2083-2092.
34. Nasim,W., Ahmad, A., Bano, A., Olatinwo, R., Usman, M., Khaliq, T., Wajid, A., Hammad,M., Mubeen, M., and Hussain, M. (2012). Effect of nitrogen on yield and oil quality of sunflower (*Helianthus annuus* L.) hybrids under sub humid conditions of Pakistan. American J. Plant Sci., 3: 243-251.
35. Patel, H.M., A.M. Bafna and Z.N. Patel, 2010. Yield and quality of castor as affected by INM. Green Farming, 1(3): 263-265.
36. Patra, A. K., Tripathy, S. K. and Samui, R. C., 1995, Response of summer groundnut to potassium with varying levels of nitrogen. J. Oilseeds Res., 12 (1): 83-86.
37. Rafey, A., Tewary, R.K. and Srivastava, V.C. 1988. Effect of nitrogen and phosphorous on linseed. Indian Journal of Agronomy, 33(3): 334-335.
38. **Raja A., Omar Hattab K., Gurusamy, L., Vembu G. and Suganya S. 2007. Sulphur application on growth and yield and quality of sesame varieties. International J. Agric. Res. 2 (7): 599-606**
39. Rao, Ch. M. and M.S. Venkateshwarlu, 1998. Effect of plant densities, irrigation and graded dose of N on oil content and nutrient uptake in castor. J. Res. APAU, 16(1): 43-46.
40. Reddy, Ch.P., Lakshmi, G.S. and Santharam, M.V. (1994). Effect of levels of nitrogen and azospirillum inoculation on oil, protein content and oil yield of safflower and on N, P, K uptake. J. of Oilseeds Res., 11(1): 34-39.
41. Sharma, R.K. 1996. Seed yield, quality and economics of soybean as influenced by levels and sources of sulphur. Annals of Agricultural Research New series, 24(1) 354 – 357.
42. Shivakumar B.G., Ahlawat I.P.S. 2008. Integrated nutrient management in soybean (*Glycine max*)- wheat (*Triticumaestivum*) cropping system. Indian J. Agronomy, 53(4): 273-8.
43. Singh, K.C. and Singh, R.P. (1977). Intercropping of annual grain legumes with sunflower, Indian J. Agric. Sci., 47: 563-564.
44. Singh, R and Rai, R.K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) influenced by integrated nutrient management. Indian J. Agronomy, 49(4):271-274.
45. Singh, R.K and Singh, A.K. 2013. Effect of nitrogen, phosphorus and sulphur fertilization on productivity, nutrient-use efficiency and economics of safflower (Carthamus tinctorius L.) under late-sown condition. Indian J. of Agronomy, 58(4):583-58.
46. Singh, S.B., Chauhan, Y.S. and Verma 1992. Effect of row spacing and nitrogen level on yield of safflower (Carthamus tinctorius L.) in salt affected soils. Indian J. of Agronomy, 37(1): 90-92.
47. Singh, S.P., Dixit, R.S. and Singh, G.R. 1997. Effect of irrigation and nitrogen on yield and quality of linseed (*Linum usitatissimum* L.). J Oilseed Res., 14(2): 229-232.
48. Subhani, A., Shabbir, G., Fazil , M., Mahmood, A. and Khalid, R. 2003. Role of sulphur in enhancing the oil contents and yield of rapeseed under medium rainfed conditions. Pakistan Journal of Soil Science. 22(4): 50 –53
49. Sudhir Singh Bhadauria (1999). Yield and quality of safflower as affected by N and P application. J. of Oilseeds Research, 16(1): 139-140.
50. Tadayyon, A., Beheshti, S.and Pessarakli, M. 2017. Effects of sprayed humic acid, iron, and zinc on quantitative and qualitative characteristics of niger plant (*Guizotia abyssinica* L.), Journal of Plant Nutri., 40:11, 1644-1650
51. Taleshi, K., Shokoh, A., Rafiee, M., Noormahamadi, G. and Sakinejhad, T. 2012. Effect of vermicompost and nitrogen levels on yield and yield components of safflower under late season drought stress. Internl. J. of Agronomy and Plant Prod., 2(1): 15-22.
52. Talukdar, M., Bhadoria, P. B. S. and Mahapatra, S. C. 2016. Impact of nitrogen fertilizer from organic and conventional sources on seed yield of Niger (*Guizotia abyssinica* Cass.). International Journal of Agronomy and Agricultural Research. 9 (1): 16-24
53. Thakur, D.S., Patel S.R. and Nageshwar L. 1998. Yield and quality of sesame as influenced by nitrogen and phosphorus in light textured inceptisols. Indian J. Agron, 43(2):325-328.
54. Tomar, R.S. and Tomar, A.S. (2013). Study on best sources and level of sulphur for Oil and Protein in linseed crop. TECHNOFAME-A Journal of Multidisciplinary Advance Research, 2(2): 7-8.
55. Varényiová, M., Ducsay, L. and Ryant, P. 2017. Sulphur nutrition and its effect on yield and oil content of oilseed r ape (*Brassica napus* L.). Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis. 59 (2): 555-562
56. Vashishtha, R.P. (1993). Influence of nitrogen and phosphorus application on the yield, and oil content of linseed. Indian Journal of Agronomy, 38(1): 64-67Kachapur, M.D., Radder, G.D. and Biradar, B.N. (1980). Quality studies in niger genotypes in relation to spacing and fertility levels. *Oilseeds J.,* 11: 38-41.
57. Walker, K. C. and Booth, E. J. 2003. Sulphur nutrition and oilseed quality. In: Abrol , Y.P. and Ahmad, A . (Eds.). Sulphur in Plants. Kluwer Academic Publishers: Dordrecht, 323–339.
58. Zaman, A. (1988). Effect of nitrogen and phosphorus on yield attributes, seed yield and oil content of irrigated safflower in laterite soil. Annals of Arid Zone, 27(1): 37-40.
59. Zaman, A. and Das, P.K. (1991). Effect of irrigation and nitrogen on yield and quality of safflower. Indian J. of Agronomy, 36(2): 177-179.
60. Zheljazkov, V.D., Vick, B.A., Baldwin, B.S., Buehring, N., Astatkie, T. and Johnson, B. 2009. Oil content and saturated fatty acids in sunflower as a function of planting date, nitrogen rate, and hybrid. Agronomy J. 101: 1003-1011.
61. Zheljazkov, V.D., Vick, B.A., Ebelhar, M.W., Buehring, N., Baldwin, B.S., Astatkie, T. and Miller, J.F. 2008. Yield, oil content and composition of sunflower grown at multiple locations in Mississippi. Agronomy J. 100: 635-642.