Some Aspects of Mineral and Organic Nutrition for Improved Yield and Oil Contents of Mustard (Brassica Juncea)

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Abstract

Fertilizers are a powerful control instrument for plant products. For more objective estimation of the role of fertilizers in development and crop formation of mustard (Brassica juncea), it is necessary to have data on rates and character of absorption of nutrients. The maintenance and as the sizes of receipt of nitrogen, phosphorus and potassium culture crops depended on their features and nutrient conditions.The experiment was conducted during the 2008-2009 (2009), 2009-2010 (2010) and 2010-2011 (2011) growing seasons on a meadow chestnut soil at the experimental station "Agrouniversity" of the Kazakh National Agrarian University of Almaty in Kazakhstan to evaluate the effect of mineral and organic fertilizers, their combination on nutrient uptake, yield and oil content of mustard (Brassica juncea) in short crop rotations (three year rotations). Fertilizers rate had a significant effect on N, P, and K at all vegetation stages. It has been established that annual application of $N_{75}P_{50}K_{45}$ mineral fertilizers or 30 Mg/ha of cow dung a time in three year is necessary to get the seed yield 2.32 and 2.18 Mg/ha. With fertilization, the product quality enhances, i.e. crude oil content, which maximum quantity was recorded in case of manure and vermicompost treatments.

Introduction

The key trends of stable agricultural business industry development in Kazakhstan involve working on new high-performance agricultural technologies in terms of cultivation of nonconventional crops ensuring increase in their productivity with simultaneous soil conservation and reproduction. Under these circumstances, the oil crops such as castor-oil plant, brown mustard and flax, which have a high oil content and yielding capacity, along with wheat, sugar beet, corn, soya, safflower, etc. are expected to be very promising for the South-East region of the republic. They are valuable because oil seeds can be used not only for production needs, but also for technical needs [1].

Fertilizers are one of the factors ensuring increase of seed yield and quality improvement with simultaneous soil preservation and fertility enhancement. Irrigation and fertilizer management are important agronomic practices for a higher yield. Irrigation facilitates mustard growth and yield in addition to water need. It also ensures availability of different nutrients in crop plants [2]. The alternative fertilization system increases nitrate-N accretion (by 8.7-15.7%) and labile phosphorus (by 5.6-14.5%) to a less extent than the conventional system, but results in organic matter growth by 0.02-0.05% versus its initial content. The chemical soil load decreases by 30% versus the conventional fertilization system, while its productivity decreases only by 2-10%. The organic fertilization system efficiency is low in the irrigated crop rotation. The yield decreases by 31%, and the entire crop rotation productivity decreases by 21-27% in the compared cases versus the conventional fertilization system [3]. Treating with $N_{60}P_{60}K_{40}$ enabled to increase mustard plant conservation by 7.6% and increase the height by 1.2-8.6 cm at all development stages versus the control treatment [4]. R. Patel, Meisheri and J.R. Patel specified that

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the seeds yield, and straw yield to a greater extent had enhanced in case of increased quantity of organic and nitrogen fertilizers, while the nitrogen content clearly correlated to the seeds yield [5]. Sugave and Sheike established in their studies that the seeds yield for about 2 years had made 12,7; 17,2; 19,4; and 20,1 kg/ha^{-1} in case of nitrogen application in the quantity of 0, 40, 80 and 120 kg/ha [6]. In this context, a task was set to study the effect of different quantities of mineral and organic fertilizers on the nutrient absorption by mustard plants, their productivity and oil content in the mustard seeds.

Materials and Methods

Fields details

The study was conducted at the "Agrouniversity" Experimental Station of the Kazakh National Agrarian University, located in the northwestern part of the Almaty region, Kazakhstan during the 2009 and 2011 growing seasons. The climate of the study area is characterized as strongly continental with an average annual rainfall of 350-420 mm. During the growing season, the precipitation ranges from 120-300 mm. The study area is located in a foothill desert-steppe region with elevations of 550-700 meters above sea level. This region is crossed by a several mountain rivers and streams. Ground water is located at a depth of 1.2-1.6 m in many parts of this region and currently is an economic source of irrigation water. The four-year rotation was used in due course of time and space with the following crop rotation: 1 – barley; 2 – flax; 3 – mustard; 4 – castor-oil plant. Oil crop fertilizers in the crop rotation and mustard single-crop were studied using the following options: 1 – Control (without fertilizer); 2 – Recommended $N_{75}P_{70}K_{45}$ rate; 3 – ½ Recommended $N_{75}P_{70}K_{45}$ rate; 4 – Cow dung, 30 Mg/ha; 5 – ½ Cow dung + ½ NPK; 6 – Vermicompost, 3 Mg/ha; 7 – Straw, 5 Mg/ha. Nitrogen fertilizers were applied as ammonium nitrate (NH_4NO_3 – 32-34% N). Phosphorus fertilizer was also applied in the form of single superphosphate ($Ca(H_2PO_4)$,$CaSO_4 \cdot 2H_2O$) (18-19% P_2O_5) and potassium fertilizer - potassium sulfate (46-50% K_2O).The content of nitrogen, phosphorus and potassium in cow dung is defined: N – 0.52%, P – 0.225%, K – 0.635% and in vermicompost – N – 288 mg/kg, P – 748 mg/kg, K – 8775 mg/kg. A straw chemical compound: N – 0.33%, P – 0.18%, K – 0.8%. The soils at the study site were a meadow chestnut soil with 4.38% organic matter content and pH of 7.8, total phosphorus, nitrogen and potassium contents of 0.211, 0.258 and 2.85% respectively. Soil parent materials are loamy loess deposits underlain by gravelly deposits. The study was conducted on two soil areas with differing plant available soil phosphorus (P) levels at the beginning of the study to evaluate the effects of inherent soil P levels produced on mustard production. The first area was on soil that had no recent fertilizer P added with soil plant available P levels of 18-20 mg P/kg soil. The second area had 150 kg P_2O_5 added as single superphosphate (18-19% P_2O_5) prior to the study resulting in initial soluble plant available P levels of 35-38 mg P/kg soil at the beginning of the study. Soil moisture content was maintained at levels of 60-70% WHC by 3-4 water applications at a rate of 600-750 m^3 ha^{-1} during the growing season.

Sample preparation and analytical methods

The plots were arranged in a randomized complete block design with three replications. Plant samples were collected using individual trials selected from five points of each trial plot using an envelope method. These mixed samples were selected out of all three trial replications. Plant samples were obtained as leaves at a rosette stage, leaves and stalks at budding and blossoming stages and seeds at a harvest for nutrient analysis. Organic matter was determined by the Tyurin procedure; total P and K were measured by flame photometry; total N was determined by the Kjeldahl method [7]. The yield structure is prior to harvesting in all cases at two non-adjacent surfaces. We determine the total number of plants in sample areas, plant heights, number of their seeds and their mass, as well as seed biological yield. Yield accounting is performed using a continuous weight method, while biological yield accounting is made using a sheaf selection method, i.e. 2 m^2 from each trial field and from all three replications. Actual yield accounting was carried out when harvesting using Sampo combine, i.e. 130 m^2 from each trial field. Yield accounting was carried out on a manual and field trial basis using fourfold number of replications in the trials. Oil content was determined by taking 100 g seeds from each treatments and oil was extracted by Soxlet method [7].

Statistical data processing was made using generally accepted methods [8].

Results and Discussion

To assess the fertilizers role in mustard yield formation more objectively, we need to have information on the rates and nature of nutrient absorption to talk about quality and quantity of growth processes. The studied types and combinations of mineral and organic fertilizers influenced differently the nutrient absorption by mustard plants. As presented in Table 1, an unambiguous decrease is observed in nitrogen concentration during the crop vegetation period, irrespective of the nutrient status.

Table 1
Effects of fertilizer treatment on nitrogen uptake by mustard under two soil P regimes (averages for 2009-2011 growing seasons)

Fertility Treatment	Nitrogen Content			
	Rosette	Budding stage	Blossoming stage	Harvest
	----------%----------			
	Low P Soil (18-20 mg P/kg soil)			
Control	4.3	2.7	1.7	3.2
Recommended $N_{75}P_{70}K_{25}$ Rate	5.3	3.5	2.3	4.7
½ Recommended $N_{75}P_{70}K_{25}$ Rate	4.8	2.9	1.9	3.8
Cow Dung (30 Mg/ha)	4.8	3.3	2.2	4.3
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	5.1	3.6	2.1	3.9
Vermicompost (3 Mg/ha)	5.2	3.3	2.1	3.6
Straw (5 Mg/ha)	4.8	3.0	1.9	3.4
	High P Soil (35-38 mg P/kg soil)			
Control	4.7	3.1	1.8	3.2
Recommended $N_{75}P_{70}K_{25}$ Rate	5.3	3.5	2.2	4.1
½ Recommended $N_{75}P_{70}K_{25}$ Rate	5.2	3.2	2.0	3.6
Cow Dung (30 Mg/ha)	4.9	3.1	2.1	4.5
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	5.5	3.6	2.1	4.0
Vermicompost (3 Mg/ha)	4.8	3.0	1.8	3.3
Straw (5 Mg/ha)	4.7	2.9	1.7	3.4

The nitrogen concentrators in ontogenesis are different mustard elements such as leaves at a rosette stage, leaves and stalks at a budding and blossoming stages and seeds at a harvest. It should be noted that nitrogen intake by mustard plants was intensive up to the blossoming stage. Then its content in leaves and stalks dipped down due to element transformation in seeds. The nitrogen content in seeds enhances at harvest due to nitrogen outflow from vegetative organs to reproductive organs. The research results demonstrated that mineral and organic fertilizers facilitated an obvious increase in nitrogen content at all vegetation stages, improving the soil nutrient status. Thus, the nitrogen content in the control treatment was 4.3% at the rosette stage, while in case of recommended $N_{75}P_{70}K_{25}$ rate, 30 Mg/ha of cow dung and 3 Mg/ha of vermicompost, it was 5.3%, 4.8%, 5.1%, at the budding stage – 3.5%, 3.3%, 3.3%, and at the blossoming stage – 2.3%, 2.2%, 2.1%, accordingly. Like for all oil crops, the phosphorus content had a determining impact on oil formation processed in mustard plants.

The difference between two options is not essential in terms of P content, unlike the nitrogen difference (Table 2). The higher content for all options was in case of higher labile phosphorus content in the soil. The phosphorus concentration decreased with crop growth and development. The maximum phosphorus content was recorded in case of applied organomineral fertilizers, i.e. ½ of cow dung + ½ of recommended $N_{75}P_{70}K_{25}$ rate at all stages, except for harvesting period.

Table 2
Effects of fertilizer treatment on phosphorus uptake by mustard under two soil P regimes
(averages for 2009-2011 growing seasons)

Fertility Treatment	Phosphorus Content			
	Rosette	Budding stage	Blossoming stage	Harvest
	----------%----------			
	Low P Soil (18-20 mg P/kg soil)			
Control	1.12	1.03	0.72	0.24
Recommended $N_{75}P_{70}K_{25}$ Rate	1.44	1.29	1.03	0.31
½ Recommended $N_{75}P_{70}K_{25}$ Rate	1.59	1.24	1.01	0.32
Cow Dung (30 Mg/ha)	1.39	1.22	0.94	0.36
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	1.58	1.42	1.04	0.30
Vermicompost (3 Mg/ha)	1.14	1.01	0.72	0.30
Straw (5 Mg/ha)	1.31	1.14	0.87	0.31
	High P Soil (35-38 mg P/kg soil)			
Control	1.39	1.19	0.94	0.30
Recommended $N_{75}P_{70}K_{25}$ Rate	1.59	1.26	1.14	0.34
½ Recommended $N_{75}P_{70}K_{25}$ Rate	1.63	1.37	1.09	0.28
Cow Dung (30 Mg/ha)	1.74	1.27	1.19	0.33
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	1.86	1.38	1.26	0.32
Vermicompost (3 Mg/ha)	1.37	1.18	0.89	0.32
Straw (5 Mg/ha)	1.39	1.21	0.94	0.22

The fertilizers still had a positive impact on the element concentration versus the control treatment. As shown in Table 3, all fertilized cases relative to the control treatment raised the element concentration at the rosette stage.

Table 3
Effects of fertilizer treatment on potassium uptake by mustard under two soil P regimes
(averages for 2009-2011 growing seasons)

Fertility Treatment	Potassium Content			
	Rosette	Budding stage	Blossoming stage	Harvest
	----------%----------			
	Low P Soil (18-20 mg P/kg soil)			
Control	4.52	3.67	2.17	1.28
Recommended $N_{75}P_{70}K_{25}$ Rate	4.86	4.00	2.05	1.22
½ Recommended $N_{75}P_{70}K_{25}$ Rate	4.64	3.84	1.99	1.16
Cow Dung (30 Mg/ha)	4.57	3.72	1.86	1.34
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	4.60	3.74	1.88	1.31
Vermicompost (3 Mg/ha)	4.64	3.81	1.93	1.33
Straw (5 Mg/ha)	4.77	3.91	2.04	1.29
	High P Soil (35-38 mg P/kg soil)			
Control	4.68	3.80	2.32	1.22
Recommended $N_{75}P_{70}K_{25}$ Rate	5.02	4.15	2.24	1.23
½ Recommended $N_{75}P_{70}K_{25}$ Rate	4.81	4.03	2.19	1.22
Cow Dung (30 Mg/ha)	4.77	3.91	2.06	1.39
½ Cow Dung + ½ $N_{75}P_{70}K_{25}$ Rate	4.79	3.93	2.06	1.32
Vermicompost (5 Mg/ha)	4.79	3.96	2.13	1.30
Straw (5 Mg/ha)	4.94	4.04	2.20	1.28

The K content in plants was reduced by 2.34 times in the interstage period – rosette-blossoming. No significant effect of fertilizers on potassium concentration in mustard plants was found. The potassium concentration at the blossoming stage relative to the control was reduced in all cases. When harvesting the element content in all cases, including full and half of recommended $N_{75}P_{70}K_{25}$ rate was less by 0.06-0.12%. It is, most likely, the result of a lot of accumulated dry mustard weight in all cases with applied mineral fertilizers, and, considering rather high potassium concentration in the soils, we are able to explain so insignificant effect of fertilizers on the potassium accretion in plants. Sheikh et al. reported that nitrogen, phosphorus and potassium uptake by mustard was increased with increasing rates of cow dung treatment (10 Mg/ha, 20 Mg/ha) [9].

Table 4
Effects of fertilizer treatment on the seed yield of mustard

Fertility Treatment	Low P Soil				High P soil			
	2009	2010	2011	Mean	2009	2010	2011	Mean
	----------Mg/ha----------							
Control	1.78	1.51	175	1.68	2.09	1.70	1.93	1.91
Recommended $N_{75}P_{70}K_{25}$Rate	2.36	2.12	249	2.32	2.46	2.25	2.55	2.42
½ Recommended $N_{75}P_{70}K_{25}$ Rate	2.09	1.78	193	1.93	2.15	1.95	2.18	2.09
Cow Dung (30 Mg/ha)	2.56	1.97	200	2.18	2.69	2.15	2.25	2.36
½ CD + ½ $N_{75}P_{70}K_{25}$ Rate	2.32	1.90	214	2.12	2.62	2.08	2.40	2.37
Vermicompost (3 Mg/ha)	2.57	1.98	190	2.15	2.64	2.08	2.11	2.28
Straw (5 Mg/ha)	1.83	1.71	195	1.83	2.14	1.81	2.12	2.02
LSD (0.05), Mg/ha	0.310	0.246	0.472		0.361	0.398	0.252	
SEM	1.36	1.48	1.24		1.53	1.32	1.50	

Mustard yield is quantitative expression of integrated agrotechnical and agrochemical interaction with the environment. It is obvious that high and stable yields can be obtained by satisfying the plant needs in nutrient elements and water during their growth and development. In case of mustard cultivation in irrigated conditions, the food element ratio in applied fertilizers is very important in yield formation (Table 4).

Table 5
Effects of fertilizer treatment on oil content of mustard having two soil P regimes including effects of differences due to basal P levels (averages for 2009-2011)

Fertility Treatment	Low P Soil				High P soil			
	2009	2010	2011	average for 2009-2011	2009	2010	2011	average for 2009-2011
	---------- Oil Content %----------							
Control	43.12	38.73	34.16	38.67	47.11	40.86	40.34	42.77
Recommended $N_{75}P_{70}K_{25}$Rate	44.72	40.54	38.73	41.33	48.0	39.51	40.29	42.60
½ Recommended $N_{75}P_{70}K_{25}$ Rate	48.08	40.21	38.70	42.33	48.42	39.46	39.62	42.50
Cow Dung (30 t/ha)	48.98	39.52	39.99	42.83	49.83	39.59	40.39	43.27
½ CD + ½ $N_{75}P_{70}K_{25}$ Rate	46.51	40.01	38.49	41.67	48.02	40.68	39.31	42.67
Vermicompost (3 t/ha)	49.12	39.45	34.94	41.17	50.44	39.58	41.29	43.77
Straw (5 t/ha)	47.34	40.03	39.62	42.33	47.11	40.12	39.76	42.33
LSD(0.05)	2.10	1.70	1.39		1.84	2.76	2.68	
S_x	1.69	1.56	1.46		1.61	1.58	1.55	

The regularity of fertilizers effect is quite clear in our study. The yield varied to a wide extent depending on the nutrition. The analysis of triennial data shows that the yield level of 1.68 Mg/ha without fertilizers was quite high in the meadow chestnut soil and applying the recommended $N_{75}P_{70}K_{45}$ rate for about three years definitely exceeded mustard productivity and was 2.32 Mg/ha. Sugave and Sheike pursued their studies and found that seed production on average for 2 years had been 1.27; 1.72; 1.94; and 2.01 Mg/ha when applying 40, 80 and 120 kg/ha of nitrogen [6]. Jadnav et al. proved in their studies that the greatest seed production (1.07 Mg/ha) had been obtained in case of band nitrogen fertilization in two stages versus treating with all fertilizer quantity whilst planting or partial fertilizing by spreading [10]. Studying the test results, an arrived at the conclusion that the heaviest yield was in N case (which is 73% more than in case of control treatment without nitrogen fertilizers). In case of bigger quantities there was excessive vegetative growth harmful for seed production [11]. The positive effect of phosphoric fertilizers on mustard productivity was also studied in works [12], [13]. The maximum additional yield versus the treatment without fertilizer was obtained at the expense of vermicompost application in 2009, and in 2010 and 2011 in case of recommended $N_{75}P_{70}K_{25}$ rate. The weather conditions had a significant effect on yield, so the maximum yield values were obtained in the favorable year 2009 unlike 2010 and 2011. Both separate and joint application of mineral and organic fertilizers results in essential crop improvement versus the control in case of natural, and raised P_2O_5.

Improvement of product quality is one of the factors for agricultural product intensification. A yield quality means the chemical compound of obtained product, which this crop is planted for. This is protein content for one plant, and oil, starch etc. – for others. The determined quality of seeds under our investigation has shown that mineral fertilizers had influenced positively the qualitative indicators (oil content) and their derivative value along with crop improvement (Table 5). Thus, applying the recommended (half and full) rate of fertilizers enabled the increase of oil concentration in mustard seeds by 2.66-3.66% in contrast to control variant (38.67%).

Admitting fertilizers importance in oil formation, Sugave et al. came to the conclusion that nitric fertilizers had not a significant effect on oil content and had raised protein content in the seeds. Treating with nitrogen of 0, 40, 80 and 120 kg/ha, the oil content in seeds was 38.74; 38.87; 38.58 and 38.52% [6]. However, Ahmad et al. studied the effect of 40 and 60 kg/ha of sulfur and nitrogen (60, 100 and 150 kg/ha) and their combinations on the oil content in mustard seeds and noted that joint treatment with sulfur and nitrogen fertilizers had increased oil content in mustard seeds [14]. The maximum oil content was 51.2% when treating with 60 kg/ha of sulfur + 100 kg/ha of nitrogen. In case of cow dung (30 Mg/ha) and vermicompost (3 Mg/ha) treatment, the oil content was also higher than the reference one, i.e. 42.83% and 41.67% respectively. The oil content was higher in case of higher level of labile phosphorus content in the soil (P_{150}). It should be noted that the absolute indicators of seeds oil content in the wet year 2009 were higher, i.e. 43.12%, in case of natural agrochemical background they were 44.72-49.12%, which was higher than the similar indicators in 2010-2011.

The mustard seed oil quality was assessed in accordance with GOST standards using physical and chemical indicators such as acid number, iodine number, and saponification number (Table 6).

Table 6

Effects of fertilizer treatment on a quality of oil of mustard (averages for 2009-2011)

Fertility Treatment	Iodic number, mg / 100 g	Saponification number, mg	Acid number, mg KOH/g	Free fatty acids, %
Control	97.5	175	3.65	1.84
Recommended $N_{75}P_{70}K_{25}$ Rate	100.0	178	3.25	1.62
Cow Dung (30 Mg/ha)	99.5	175	3.75	1.88
Vermicompost (3 Mg/ha)	102.0	182	3.90	1.96

As the iodine number specifies the content of unsaturated compounds in oil, using different fertilizers enables to increase the iodine number from 98 to 102 units towards the control, which has a positive impact on oil formation processes and quality both for technical and food needs. High-quality food and technical oils shall contain the minimum quantity of free fat acids. Thus, in case of $N_{75}P_{70}K_{25}$ introduction, free fat acids decreased up to 1.61%, while in other cases free fat acids increased (between 1.91 and 1.96). The saponification number varies between 171 and 182 units. It is minimal in case of cow dung treatment, and maximum – in case of vermicompost treatment.

Conclusions

Thus, the studies have shown that mineral and organic fertilizers make essential impact on nutrient content in plants of mustard, in turn, positively affects productivity and quality indicators of mustard seeds – oil. From the above discussion, it may be concluded that recommended $N_{75}P_{70}K_{25}$ rate can be applied for maximum yield of mustard (sort Rushena) and oil content was highest in variant of cow dung.

References

1. Sariev, N.A., Mechanize production of mustard. Oil cultures. 5 :11-12 (1983).
2. Piri, I., Nik, M.M., Tavassoli, A., Rastegaripour, F., and Babaeian, M., Effect of irrigation frequency and application levels of sulfur fertilizer on water use efficiency and yield of Indian Mustard (Brassica juncea). African Journal of Biotechnology 10(55): 11459-11467 (2011).
3. Suleimenova, M.Sh., Photosynthetic activity and productivity of irrigated crops. In: The problems of stabilization and development of agriculture in Kazakhstan, Siberia and Mongolia. Almaty, 20 October 2000. pp: 79-80 (2000).
4. Ramazanov, A.U., Shurmanbaev, N.Sh. and Grishanova, Y.N., Cultivation of mustard on oilseeds in northern Kazakhstan. Researches and results 3: 194-196 (2008).
5. Patel, R.H., Meisheri, T.G. and Patel, J.R., Yields, nutrient content and uptake by Indian mustard (Brassica juncea) Czernj and Cossonj as influenced by FYM, nitrogen of fertilizer. Gujarat. Agr. Univ/ Res. J. 23(2): 1-8 (1998).
6. Sugawe G.T. and Shelke, V.B., Response of mustard to various levels of irrigation and nitrogen. J. Maharashtra Agr. Univ. 22(3): 316-317 (1997).
7. In V.G. Mineev (ed.), Practical works in agricultural science, MSU, Moscow, 2001, p.689.
8. B.A. Dospehov, Guidelines for field experiment, Kolos, Moscow, 1979, pp: 416-417.
9. Sheikh, S.Z., Quazi, F.Q., Chowdhury, M.A., Adnan, A.W., Effect of different animal manures on yield quality and nutrient uptake by mustard cv. Agrani. BRAC University Journal, 1(2): 59-66 (2004).
10. Jadhav, N.D., Jadhav S.N. and Khanvilkar, S.A., Response of mustard (Brassica juncea) variety Varuna to irrigation of nitrogen application. Maharashtra Agr. Univ. 23(3): 309-310 (1998).
11. An, H.H., Nong nighiep thuc pham. Agr. and Food Ind. 4: 419-421 (1999).
12. Mir, M.R., Mobin, M., Khan, N.A., Bhat, M.A., Lone, N.A., Bhat, K.A., Razvi, S.M., Wani, S.A., Wani, N., Akhter, S., Rashid, S., Masoodi, N. H. and Payne, W.A., Effect of fertilizers on yield characteristics of mustard (Brassica juncea L. Czern&Coss). Journal of Phytology 2(10): 20-24 (2010).
13. Singh, V., Lothi M.and Verma N. K., Effect of phosphorus and sulfur levels on growth and yield of mustard (Brassica juncea Coss) variety 'Varuna'. Agric. Sci. Digest. 28 (1): 59-60 (2008).
14. Ahmad, A., Abraham, G. and Abdin, M.Z., Physiological investigation of the impact of nitrogen and sulphur application on seed and oil yields of rapeseed (Brassica campestris L.) and mustard (Brassica juncea L. Czem. And Coss.) genotypes. J. Crop Sci. (183)6: 19-25 (1999).

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