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Effects of Thiamine Hydrochloride on plant growth and nutrient uptake of mustard

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Abstract

A factorial randomized field experiment was conducted to study the seed soaking effect of different concentrations of thiamine hydrochloride solution on two mustard cultivars. The seeds of mustard (*Brassica juncea* L. Czern & Coss.) cultivars 'Rohini' and 'Varuna' were soaked in 0.01, 0.02, 0.03% aqueous solutions of thiamine hydrochloride along with water soaked control. A uniform basal dose of 90kg N, 30kg P and 30kg K/ha were given to soil at the time of sowing in the form of urea, mono calcium super phosphate and muriate of potash respectively. The effect of these treatments was observed on shoot length, dry weight/ plant, leaf area, leaf area index and nitrogen content and its uptake at 40, 60, 80, 100 and 120 days after sowing (DAS), crop growth rate, relative growth rate and net assimilation rate at 0-40, 40-60, 60-80, 80-100 and 100-120 days. In general plants rose from 0.03% soaking treatment enhanced values for various parameters studied, whereas in between two tested varieties, 'Varuna' performed better. Interaction effect of soaking × variety was found to be non-significant for the most of the characters studied except for the dry weight, CGR and RGR. For dry weight it was significant at 100 and 120 DAS whereas for CGR the interaction effect was significant only between 40-60 DAS period. It was found that values for variety Rohini at water soaked control and 0.03% treatments were significantly different and were at par with 0.01 and 0.02% treatments. Interaction effect of RGR was found to be only significant at final stage, where it was found that variety Varuna at 0.02% treatment gave significantly inferior value to 0.01 and 0.03% treatments, whereas variety Rohini at 0.02% treatment was significantly superior to these two other treatments. In case of nitrogen uptake at all sampling stages, 0.03% thiamine hydrochloride again proved to be the best and gave significantly higher values than water soaked control which were 75.14, 35.5, 41.49, 19.41 and 20.13 percent more at 40, 60, 80, 100 and 120 DAS respectively. Though the interaction effect was found to be non-

significant at all the sampling stages, it was maximum with variety Varuna and 0.03% thiamine solution. In the present study, it has been found that the soaking of mustard seeds (variety Varuna) in 0.03% thiamine hydrochloride solution ensured better growth and nutrient uptake under the local condition.

Nowadays, the demand of oil seeds increases day by day as they play significant role in the country economy. Therefore, it is necessary to raise the production of oil seeds to establish the equilibrium between demand and production. The average productivity of oil seed crops in India is low as compared to other developing countries[45]. Among the several reasons of low production of oil seeds in India, the most important are the marginal holding of lands to the 75% farmers, irrigation of 15% area under oil seeds as compared to 72% under wheat and 44% under rice; poor soil fertility status and sub-optimal use of fertilizers[28,35]. Due to difficulties in increasing the acreage of cultivation, adaptation of good agricultural practices and use of high yielding varieties can be beneficial for improved productivity of these important crops. A positive role of judicious application of fertilizers in crop growth and development has been established by numerous investigators[6,23,32,40]. However, application of inorganic fertilizers in excess not only affects the quality of the product but also causes threat to the environment. To overcome the ill effect of excess use of inorganic fertilizers, agriculturist and farm scientists are now focusing on using the natural and safe substances in order to improve the plant growth.

Different vitamins have been reported to functions as growth regulators or hormone precursors and found to have synergistic effects on both growth and yield of many plant species[27,41]. It has also been studied that vitamin B helps in proliferation of root system which lead to better water and nutrient absorption[4,18,30,34,39]. Furthermore, the exogenous application of vitamins have been reported to have profound effect on the factors regulating plant growth which may ultimately influence several physiological process and also protect plant from harmful effects of environmental stress[31,33]. These vitamins also act as scavenger for free radicals originated during different metabolism processes which may affect the permeability of plasma membrane by the oxidation of membrane lipids[10,11] and also prevent the degradation of tissues caused by free radicals[7]. Thiamine (Vitamin B_1), one of the members of vitamin B group, serves as co-enzyme thiamine pyrophosphate in dcarboxylation of α-keto acids such as pyruvic acid and keto-glutamic acid and plays an important role in the metabolism of carbohydrate and fat[5,15,27]. Thiamine also plays significant role in transketolation reactions of the pentose phosphate cycle, which provides pentose phosphate for the synthesis of nucleotide and to generate reduced form of NADP required for various biosynthetic pathways[8]. Increase in vegetative growth and chemical constituents of certain plants by application of thiamine

have been well studied[1,47]. However, Sajjad and Samiullah[35,36] also reported the beneficial effect of thiamine hydrochloride as pre-sowing seed treatment on growth and yield of mustard. In present communication efforts have been made to study the comparative performance of two varieties of mustard by seed soaking application of thiamine on the improvement of growth and nutrient uptake.

This experiment was conducted with the aim to study the comparative performance of two mustard (*Brassica juncea* L.) varieties namely, Varuna (V_1) and Rohini (V_2) treated with different concentrations of thiamine hydrochloride (vitamin B1), and to select out the variety better adapted to local condition of Shahjahanpur with regard to their growth and nutrient uptake. The design of the experiment was factorial randomized block design. Seeds of these varieties of mustard were obtained from the National Seeds Corporation Ltd., New Delhi. Healthy seeds of uniform size were selected and surface sterilized with 5% sodium hypochlorite. After sterilization and viability testing, the seeds were soaked in different concentrations of thiamine hydrochloride, viz., 0.01 (S_1), 0.02 (S_2), 0.03 % (S_3) for 4 h. A water-soaked seeds (S_0) was also kept as control for the comparison[35,36]. The soil of the experiment was sandy loam with pH 8.01, conductivity 0.48 mmhos/cm, available nitrogen 224 kg/ ha, available phosphorous 22 kg/ha and available potash 223 kg/ha. Sowing was done in the second week of November. Each treatment was replicated thrice. A uniform basal dose of N, P and K fertilizers was given to the soil at the time of sowing at the rate of $N_{90}P_{30}K_{30}$ kg/ha. The source of N, P and K fertilizers were urea, monocalcium super phosphate and muriate of potash respectively. The field was irrigated thrice between sowing and harvesting. Weeding was done as per the requirement during the entire course of growth of the plants. Two sprays of insecticides (Dimecron-100) were done to check the aphid infestation which generally takes place during flowering and fruiting stages. Sampling was done at 40, 60, 80, 100 and 120 (at harvest) days after sowing (DAS) to assess the growth pattern, nitrogen content and uptake of the crop. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated for the periods 0-40, 40-60, 60-80, 80-100 and 100-120 DAS. CGR, RGR and NAR were calculated by using the formula suggested by Watson[46], Radford[29] and Milthorpe and Moorby[22], respectively. The nitrogen content of the sample was estimated spectrophotometrically according to the method established by Lindner[20].

Statistical analysis :

All experimental data were subjected to statistical analysis by adopting analysis of variance (ANOVA) technique according to the design of the experiment (Gomez and Gomez, 1984).

Growth Parameters :

This experiment was conducted to check the seed soaking effect of different concentration of thiamine hydrochloride on the comparative performance of two varieties (Varuna and Rohini) of mustard. The soaking treatments were 0.01%, 0.02% and 0.03% thiamine hydrochloride. Seed soaking in water

was maintained as control. The effect of these treatments on two varieties and of their interaction (Soaking × Variety) was observed on the following parameters. The data presented in table 1 revealed that the shoot length was significantly different between the varieties and treatment. Except 40 DAS, variety V_1 was significantly taller than V_2 at all sampling stages and variety V_1 produced 41.80 % more plant height than V_2 at 100 DAS. Regarding soaking, it is evident that at 60 and 100 DAS, control plants were shorter than that of other treatments, which were statistically equal. At 80 DAS, the values for two adjacent treatments were statistically equal, and values for alternate treatments were significantly superior as the concentration increased. At final stage, shoot length of control plants were statistically equal to S_1 treatment, whereas S_2 and S_3 treatment produced plants height, which were statistically equal and were significantly taller than that produced by S_1 treatment. At 60, 80, 100 and 120 DAS, the treatment S_3 registered 23.63, 27.18, 21.12 and 27.31 % more shoot length over control respectively. The interaction effect was found to be non-significant. The increase in the plant height with various applications of thiamine hydrochloride is in agreement with the findings of Abd El-Aziz *et al.*[1] and El-Awadi *et al.*[8]. It is evident from the table 2 that at all the sampling stages; variety V_1 registered significantly higher dry weight than the variety V_2 except at 40 DAS which behaved non-significantly. As for as soaking treatment is concerned, it is clear from the data that at all sampling stages, significantly highest and lowest values were found at S_3 and S_0 treatment respectively which was 69.32, 45.67, 41.34, 27.19 and 21.58% more dry weight for the treatment S_3 at 40, 60, 80, 100 and 120 DAS respectively. Treatment S_1 showed significantly higher value than S_0 and lower value than S_2 treatment. Except at 40 and 80 DAS, the interaction effect was significant at all other sampling stages and it was found that there was no significant difference between S_2 and S_3 treatments in variety V_2. A positive effect of thiamine on plant dry weight was also reported by Nahed *et al.*[25] on Gladiolus plants and El-Awadi *et al.*[8], on Lupin. Similar, results were also reported by Mahgoub *et al.*[23]. Data in table 3 revealed that at 40 and 80 DAS, the leaf area of plants treated with S_2 and S_3 was at par and the value were significantly higher than that obtained for S_1 treatment, which in turn was superior to control. At 60 and 100 DAS, significant maximum and minimum values were found in S_3 and control respectively. Treatment S_2 gave significantly higher values than S_1 treatment. At final stage, treatments S_2 and S_3 registered statistically equal values and were significantly superior to other two treatments, which were at par among them. Among various soaking treatments, S_3 gave 29.45, 34.24, 28.77, 45.92 and 22.08% more leaf area than control at 40, 60, 80, 100 and 120 DAS respectively. Regarding the variety, it was found that variety Varuna registered significantly more leaf area than Rohini at all sampling stages which was 30% more than Rohini at 100 DAS. However, the interaction effect was found to be non-significant. These results are in conformity with the results obtained by Sajjad and Samiullah[34] on mustard var. Varuna. Leaf area index followed the

same pattern as in case of leaf area (table 4). It is evident from the table 5 that except for the periods 0-40 DAS and 80-100 DAS, CGR was found to be significantly different for varieties between 40-60 DAS, 60-80 DAS and 100-120 DAS period. In the first two periods, *i.e.* 40-60 DAS and 60-80 DAS, variety V_1 had significantly more CGR than V_2 which was 57.5 and 112.5% more respectively and between 100-120 DAS period, variety V_2 had more CGR which was 54.67% more than V_1. CGR was significantly affected by soaking treatments at all other sampling stages, except at 80-100 DAS. Between 0-40 DAS period significantly maximum values were found for S_3 thiamine treatment and significantly minimum for control which was 69.39% more in S_3 than S_0. Treatment S_2 was significantly superior to S_1 treatment. Between 40-60 DAS period, S_0 and S_1 treatment registered statistically equal values and were significantly inferior to the other two statistically equal treatments. Between 60-80 DAS period, treatments S_1 and S_2 gave at par values and were significantly superior to that for S_3 treatment, which in turn was significantly superior to value recorded for S_0. At final stage, control registered significantly highest value, whereas all the other three treatments had statistically equal value. The interaction effect was significant only between 40-60 DAS period and it was found that values for variety V_2 at S_0 and S_3 treatments were significantly different and were at par with S_1 and S_2 treatments. As shown in table 6 Variety V_1 registered significantly higher RGR value between 40-60 DAS and 60-80 DAS period, whereas for V_2 more RGR was noted between 80-100 DAS and 100-120 DAS periods. For the period 60-80 DAS, V_1 registered 49.10% more RGR than V_2. Between 0-40 DAS period, treatments S_2 and S_3 had statistically equal values and were significantly superior to S_1, which in turn was significantly superior to control. Treatment S_3 registered 7.45% more RGR than water soaked control. Between 40-60 DAS, 80-100 DAS and 100-120 DAS, significantly highest values were found in control and all other three treatments were statistically equal in their effect. Between 60-80 DAS period, significant highest value was found in S_1 followed by S_2, S_0 and S_3 in that order. The interaction effect was significant only at final stage where it was found that variety V_1 at S_2 soaking treatment gave significantly inferior value to S_1 and S_3 treatments, whereas variety V_2 at S_2 thiamine treatment was significantly superior to these other two treatments. Improvement in CGR and RGR has also been reported by Sajjad and Samiullah[33] and Sajjad[32] by thiamine hydrochloride treatment of mustard as seed soaking and foliar treatment respectively. Data presented in table 7 showed that variety V_2 had significantly higher net NAR than V_1 between 0-40 DAS, 80-100 DAS and 100-120 DAS periods and less NAR between 40-60 DAS and 60-80 DAS periods. For the period 60-80 DAS, V_1 registered 95.52% more NAR than V_2 and between 100-120 DAS, variety V_2 showed 92.39% more NAR than V_1. Between 0-40 DAS period significant highest and lowest values were found in S_3 and for control respectively. The value found in S_1 was significantly superior and inferior to S_0 and S_2 treatments respectively. Between 40-60 DAS

period, S_0, S_2 and S_3 had statistically equal values and both control and S_3 had significantly higher values to S_1 treatment. Between 60-80 DAS, treatments S_1 and S_2 were at par in effect among them and were significantly superior to control and S_3. Between 80-100 DAS and 100- 120 DAS periods, control had significantly highest value and all the other treatments had statistically equal value. The interaction was found to be non-significant. Increased leaf area accompanied by NAR (at initial stage) resulted in increased crop CGR and higher dry weight. Correlation studies showed that leaf area at 80 DAS was well correlated with dry weight at harvest. This result is consistent with that obtained by Ansari and Khan[3]. Improvement in NAR and other growth characteristics has also been reported by several investigators on various plant species[2,32,34,36]. Youssef and Talaat[45] stated that the foliar application of thiamine boosted the plant growth of rosemary plant through enhancing the endogenous level of various growth regulators. Furthermore, Gamal El-Din[12] and El-Shawy *et al.*[9], reported the positive effect of thiamine on the growth of sunflower and flax respectively.

Biochemical Parameters:

Nitrogen uptake:

Data presented in Table 8 elucidates that Variety V_2 had more nitrogen uptake than V_1 at 40 DAS but from 60 DAS onwards V_1 had significantly higher nitrogen uptake than V_2 which was found to be 46.70% more nitrogen uptake at 80 DAS. At 40 DAS, the nitrogen uptake increased significantly as the thiamine hydrochloride concentration increased. At 60, 80 and 120 DAS, both S_2 and S_3 removed statistically equal amounts of nitrogen from soil and were significantly superior to S_1 thiamine hydrochloride treatment. Control and S_1 produced at par values at 60, 100 and 120 DAS sampling. Among the treatments at all sampling stages, S_3 thiamine hydrochloride again proved to be the best and gave significantly higher values than water soaked control which were 75.14, 35.5, 41.49, 19.41 and 20.13 percent more at 40, 60, 80, 100 and 120 DAS respectively than control. However, the interaction effect was found to be non-significant at all the sampling stages. In the present study confirmed that treatment of thiamine on plants increased the nutrient concentration by increasing the plant growth and finally more nutrients were uptaken from the soil and thereby showing increased nitrogen uptake. These results are in agreement with the findings of Rao and Reddy (1985). They concluded that B-group vitamins are highly efficient in enhancing ion uptake. Similarly, Youssef and Talaat[45] found that foliar application of thiamine increased total nitrogen, phosphorus and potassium percentage on rosemary plants. However, Sajjad[32] also reported the beneficial effect of thiamine as foliar spray on nitrogen uptake of mustard plant. Increase in nitrogen and phosphorous uptake has also been reported by Abd El-Aziz *et al.*[1]. The beneficial effects of vitamins on enhancing growth and nutritional status of the plants surely reflected on improving yield components (Khan *et al.*, 2001). As nitrogen plays many important roles in metabolic processes of the plants, its sufficient availability would act as a key factor towards wholesome improvement in agriculture production[41]. Nitrogen is not found in protein only, but also

Table 1: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on shoot length per plant (cm) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Shoot length															
Sampling stages (Days after sowing)															
40				60			80			100			120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	33.8	34.9	34.4	56.1	46.9	51.5	79.9	66.4	73.2	110.9	71.9	91.4	116.4	80.5	98.5
S_1	35.1	56.1	35.6	63.2	54.6	58.9	85.3	75.9	80.6	121.6	86.2	103.9	122.6	89.6	106.1
S_2	36.6	35.6	36.1	66.5	58.1	62.3	93.8	79.1	86.5	128.1	92.0	110.1	132.1	110.8	121.5
S_3	37.1	33.4	35.3	67.8	60.6	64.2	101.5	84.6	93.1	126.5	94.8	110.7	136.5	114.2	125.4
Mean	35.7	35.0		63.4	55.1		90.1	76.5		121.8	86.2		126.9	98.6	
CD (critical difference) at 5%															
CD for V	NS			4.8			5.1			5.8			9.2		
CD for S	NS			7.0			7.4			8.4			13.4		
CD for V×S	NS			NS			NS			NS			NS		

Table 2: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on dry weight per plant (gm) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Dry weight															
Sampling stages (Days after sowing)															
40				60			80			100			120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	6.10	5.95	6.03	18.60	14.90	16.75	30.60	20.20	25.40	38.90	28.40	33.65	42.30	32.30	37.00
S_1	7.51	6.96	7.24	20.40	16.20	18.30	36.40	24.20	30.30	42.90	31.20	37.05	45.10	33.80	39.45
S_2	9.06	9.38	9.22	26.00	18.60	22.30	43.40	27.00	35.15	47.80	32.90	40.35	48.70	36.60	42.65
S_3	10.20	10.21	10.21	27.90	20.90	24.40	43.80	28.00	35.90	51.60	34.00	42.80	53.70	37.00	45.35
Mean	8.22	8.13		23.23	17.65		38.53	24.85		45.30	31.63		47.45	34.93	
CD (critical difference) at 5%															
CD for V	NS			0.70			1.23			0.96			0.83		
CD for S	0.58			1.00			1.74			1.36			1.18		
CD for V×S	NS			NS			NS			1.92			NS		

Table 3: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on leaf area per plant (cm^2) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Leaf area															
Sampling stages (Days after sowing)															
40				60			80			100			120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	986	846	916	1348	1216	1282	1694	1419	1557	1140	819	980	994	736	865
S_1	1094	972	1033	1503	1498	1501	1916	1752	1834	1318	1042	1180	966	814	900
S_2	1201	1164	1183	1698	1527	1613	2041	1876	1959	1414	1159	1287	1094	963	1029
S_3	1246	1119	1183	1757	1685	1721	2094	1916	2005	1641	1219	1430	1200	911	1058
Mean	1132	1025		1577	1482		1936	1741		1378	1060		1069	856	
CD (critical difference) at 5%															
CD for V	49.0			55.0			64.5			49.1			50		
CD for S	70			78.0			91.0			69.4			70		
CD for V×S	NS			NS			NS			NS			NS		

Table 4: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on leaf area index of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Leaf area index															
Sampling stages (Days after sowing)															
40				60			80			100			120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	1.18	1.01	1.09	1.61	1.45	1.53	2.03	1.70	1.86	1.36	0.98	1.17	1.19	0.88	1.03
S_1	1.31	1.16	1.23	1.80	1.79	1.80	2.29	2.10	2.20	1.58	1.25	1.41	1.18	0.97	1.08
S_2	1.44	1.39	1.41	2.03	1.83	1.93	2.44	2.25	2.35	1.69	1.39	1.54	1.31	1.15	1.23
S_3	1.49	1.34	1.41	2.10	2.02	2.06	2.51	2.29	2.40	1.96	1.46	1.71	1.44	1.09	1.26
Mean	1.35	1.23		1.89	1.77		2.32	2.08		1.65	1.27		1.28	1.02	
CD (critical difference) at 5%															
CD for V	0.05			0.06			0.07			0.05			0.06		
CD for S	0.08			0.09			0.10			0.08			0.08		
CD for V×S	NS			NS			NS			NS			NS		

Table 5: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on crop growth rate (mg/ plant/day) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Crop growth rate															
Sampling stages (Days after sowing)															
0-40				40-60			60-80			80-100			100-120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	152.5	148.8	150.6	625.0	447.5	536.3	600.0	265.0	432.5	415.0	410.0	412.5	170.0	195.0	182.5
S_1	187.8	174.0	180.9	644.5	462.0	553.3	800.0	400.0	600.0	325.0	350.0	337.5	110.0	130.0	120.2
S_2	226.5	234.5	230.5	847.0	461.0	654.0	865.0	420.0	642.5	225.0	295.0	260.0	45.0	185.0	115.0
S_3	255.0	255.3	255.1	885.0	534.5	709.8	795.0	355.0	575.0	390.0	300.0	345.0	105.0	150.0	127.5
Mean	205.4	203.1		750.4	476.3		765.0	360.0		338.8	338.8		107.5	165.0	
CD (critical difference) at 5%															
CD for V		NS			40.0			31.8			NS				8.1
CD for S		14.5			56.5			45.0			NS				11.4
CD for V×S		NS			80.0			NS			NS				NS

Table 6: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on relative growth rate (mg/gm/day) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Relative growth rate															
Sampling stages (Days after sowing)															
0-40				40-60			60-80			80-100			100-120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	177.6	177.0	177.3	55.9	46.0	51.0	24.9	15.2	20.0	12.06	17.05	14.56	4.19	6.45	5.32
S_1	182.9	180,8	181.8	49.9	42.5	46.2	29.0	20.1	24.5	8.27	12.70	10.48	2.50	4.01	3.26
S_2	187.5	188.4	188.0	52.7	34.2	43.5	25.5	18.6	22.1	4.94	9.88	7.41	0.93	5.33	3.13
S_3	190.5	190.5	190.5	50.3	35.8	43.1	22.6	14.6	18.6	8.22	9.72	8.97	1.99	4.23	3.11
Mean	184.6	184.2		52.2	39.6		25.5	17.1		8.37	12.34		2.40	5.00	
CD (critical difference) at 5%															
CD for V		NS			3.6			0.7			2.53				0.26
CD for S		2.1			5.0			1.0			3.58				0.37
CD for V×S		NS			NS			NS			NS				0.52

Table 7: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on net assimilation rate (mg/ cm^2/day) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Net assimilation rate															
Sampling stages (Days after sowing)															
0-40				40-60			60-80			80-100			100-120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	7.95	8.77	8.36	5.39	4.38	4.89	3.96	2.01	2.99	3.00	3.78	3.39	1.60	2.51	2.05
S_1	9.01	9.16	9.09	5.01	3.80	4.40	4.71	2.47	3.59	2.06	2.57	2.32	0.97	1.41	1.19
S_2	10.07	10.69	10.38	5.90	3.45	4.67	4.64	2.48	3.56	1.32	2.00	1.66	0.36	1.75	1.06
S_3	10.98	11.99	11.49	5.96	3.86	4.91	4.14	1.97	3.06	2.10	1.95	2.03	0.75	1.42	1.08
Mean	9.50	10.15		5.56	3.87		4.36	2.23		2.12	2.57		0.92	1.77	
CD (critical difference) at 5%															
CD for V		0.62			0.24			0.18			NS			0.10	
CD for S		0.88			0.34			0.25			0.90			0.15	
CD for V×S		NS			NS			NS			NS			NS	

Table 8: Effect of pre-sowing seed treatment with thiamine hydrochloride for 4 hrs on nitrogen uptake (mg/ plant) of mustard (*Brassica juncea* L.) var. Varuna and Rohini

Nitrogen uptake															
Sampling stages (Days after sowing)															
40				60			80			100			120		
Varieties															
Seed Soaking	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
S_0	161	185	173	433	375	404	663	441	552	723	556	639	646	546	596
S_1	210	202	206	460	392	426	726	535	631	742	571	657	672	585	628
S_2	232	299	265	619	482	551	888	573	730	798	559	679	808	571	690
S_3	294	313	303	597	494	546	929	633	781	882	643	763	811	622	716
Mean	224	250		527	436		801	546		786	582		734	581	
CD (critical difference) at 5%															
CD for V		15			33			49			24			27	
CD for S		21			47			69			34			37	
CD for V×S		NS			NS			NS			NS			NS	

in some other important bio-molecules such as purines, pyrimidines, porphyrins and in several coenzymes. Purines and pyrimidines are the components of nucleic acids, whereas the porphyrin is found in metabolically important compounds such as chlorophyll and cytochromes, which are essential in photosynthesis and respiration. Coenzymes are essential in the functioning of many enzymes. Accordingly, nitrogen plays an important role in biosynthesis of the plant constituents through the action of different enzymes[35]. Moreover, nitrogen plays an important role in enhancing the level of phytohormones in leaves and root exudates[20,30]. Therefore, the increment in N uptake in mustard might have the positive effect of thiamine on plant growth and productivity. Khan and Srivastava[16] stated that improvement in growth and nutrient uptake of crop plants reflected in enhanced yield. The results obtained showed that the seed soaking application of mustard plants with thiamine hydrochloride significantly stimulated growth and development throughout the experimental period. Soltani *et al.*[42] found a strong correlation between vitamins B and increasing growth within plants. Several studies also showed the positive effect of vitamins on the endogenous levels of plant growth regulators, photosynthetic pigments[17,24] and in increasing the photosynthetic rate within the plants and other activities[40]. All these facts help in providing the strength to our finding regarding the reliability of thiamine in increasing growth and nutrient uptake of mustard.

Use of inorganic fertilizers can improve the productivity of the crop, but its long term application has several disadvantages. Moreover, it increases burden on our existed foreign reserves and also causes pollution hazards. Thus it is concluded from the present findings that the application of thiamine as a pre-sowing seed treatment may reduce the use of inorganic fertilizers and economize mustard cultivation as well as curtail soil pollution as B-vitamins play many significant roles in various physiological processes.

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