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Genetic variability, heritability, correlation and path analysis in fenugreek (*Trigonella foenum graecum* L.)

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Abstract

Thirty fenugreek genotypes (*Trigonella foenum graecum*L) were evaluated during *rabi* season of 2012-13 to explore its existing gene pool and identify the selection indices with an eye on a more comprehensive breeding programme. Characters like number of pods per plant, protein content in seed, days to 50% flowering and dry weight at flower initiation were found to have least variation among the coefficients both at phenotypic and genotypic level. Broad sense heritability estimates were high for protein content in seed (96.9), followed by number of pods per plant (96.7). The highest genetic advance as percentage of mean was recorded for dry matter content and dry weight at flower initiation indicating that these characters are governed by additive gene action. Correlation coefficients at phenotypic and genotypic level envisaged that biological yield was having significant and positive correlation with chlorophyll content of the leaves, number of pods per plant, straw yield per plant, 1000 seed weight, dry matter content of the plant as whole and seed yield per plant while negatively correlated with the harvest index. Path coefficient analysis revealed that biological yield per plant, harvest index, dry weight at flower initiation, chlorophyll content in leaves, number of branches per plant and 1000 seed weight were the most important characters contributing towards seed yield and hence purposeful and balanced selection based on these traits would be more rewarding for improvement of fenugreek.

Key words: Genetic variability, heritability, correlation, path coefficient analysis.

Introduction

Fenugreek (*Trigonella foenum graecum* L.), popularly known as "Methi" is an important seed spice crop largely grown in India during Rabi season. Rajasthan and Gujarat are the major fenugreek producing states followed by Madhya Pradesh in which Malwa plateau contributes a major share. In Madhya Pradesh, fenugreek growing districts are Jabalpur, Chhatarpur, Indore, Mandsaur, Neemuch, Ratlam and Shajapur.The genus *Trigonella* has two species, viz. *T. foenum-graecum* and *T. corniculata. Trigonella foenum-graecum* plants are semi-erect, tall, moderately branched with bold, typically yellow grains. fenugreek seeds are used as condiments and flavouring food preparations. They are aromatic, carminative, tonic and galactagogue. Externally they are used in poultices for boils, abscesses, ulcers and internally as emollient for inflammation of intestinal tract. The seeds contain important steroid 'diosgenin' which is used in preparation of contraceptives. Very little effort has been made in collection maintenance and utilization of different genotypes for the improvement of this crop. There is need to assess and improve the existing genotypes and introduce cultivars for seed purpose. Study of variability is a prerequisite for improvement of yield in any crop. The performance of locally available cultivars of fenugreek is poor in the Malwa region of Madhya Pradesh. Hence, an urgent need was felt for genetic improvement to develop high yielding cultivars suitable for such situations. Improvement of yield in any crop. The performance of locally available cultivars of fenugreek is poor in the Malwa region of Madhya Pradesh. Hence, an urgent need was felt for genetic improvement to develop high yielding cultivars suitable for such situations.

Materials and Methods

The experimental material comprising of thirty divergent genotypes were sown during Rabi season of 2012-13 under randomized block design with three replications at Horticulture Research Farm, College of Horticulture, Mandsaur (M.P.), India, situated in Malwa plateau in Western part of Madhya Pradesh at North latitude of 23.450 to 24.130 and 74.440 to 75.180 East longitudes at an altitude of 435.02 meters above mean sea level. This region falls under agro climatic zone No.10 of the state. Row to row and plant to plant spacing were maintained at 40 cm and 20cm respectively. Requisite agronomic package of practices were adapted to raise a healthy crop. In each replication, five plants were randomly selected and tagged for observation. Observations were recorded for ten characters, viz. days taken to 50% flowering, plant height (cm) at 90 DAS (Days after sowing), number of branches per plant at 90 DAS, dry weight per plant at initiation of flowering, number of branches per plant, days to 50 % flowering, umbel/plant, umbellets /umbel, seeds/umbel, number of pods per plant, number of seeds per pod,1000 seed weight (g), biological yield (g), seed yield per plant(g), dry matter content (g), length of pods (cm), harvest index, straw yield per plant (g), protein content in seed (%),oil content in seeds (%), chlorophyll content in leaves (%) and seed yield per plant. The recorded data were subjected to statistical analysis as suggested by Panse and Sukhatme (1985). The genotypic and phenotypic coefficient of variance was calculated as per the formula suggested by Burton (1952), Heritability and genetic advance as per Hanson *et.al* (1956) and Johnson *et al.* (1955) correlation coefficient.

Results and Discussion

The analysis of variance (Table 1) revealed that significant variability was present in the germplasm for all the characters studied. Estimates of genotypic (GCV) and phenotypic (PCV) variances indicated that in general, the phenotypic variances were higher than the corresponding genotypic coefficient of variations, indicating the masking influence of environmental factors in expression of these traits. Wide variability occurred in dry weight at flower initiation (PCV22.56, GCV21.36) followed by straw yield per plant (PCV21.63, GCV18.23), dry matter content (PCV19.06, GCV17.09), biological yield per plant (PCV17.97, GCV15.89), This indicates the presence of sufficient amount of genetic variability for these traits and can be exploited through breeding procedure for the improvement of these characters. This is in accordance with the findings of Sharma and Shastry (2008). The difference between the value of PCV and GCV was narrow for dry matter content, number of seeds per pod, 1000 seed weight and plant height, which indicates that phenotype was truly corresponding to its genotype for these characters. Characters like number of pods per plant, protein content in seed, days to 50% flowering and dry weight at flower initiation were found to be consistent in its behavior, both at phenotypic and genotypic level and having lowest coefficient of variation. It suggests that these traits were least influenced by the non genetic factors and were hence quite stable. This is in accordance with the findings of Banerjee and Kole (2004) and Naik (2012). Heritability estimates in broad sense were classified into three groups.high > 70, medium 50 - 70, and low < 50. In the present investigation broad sense heritability estimates were high for, protein content in seed (96.9), followed by number of pods per plant (96.7), dry weight at flower initiation (89.7) and chlorophyll content in leaves(87.10), Similar findings were reported by Meena *et al.* (2011) and Naik (2012). The genetic advance is more useful than heritability alone in predicting the resultant effect on selecting the best individuals. In the present investigation, expected genetic advance was recorded high with dry matter content (17.83), followed by number of pods per plant (17.39), biological yield (10.75) and plant height (10.50).This is in accordance with the findings of Prajapati *et al.* (2010) and Naik (2012). Heritability estimates along with the genetic advance are more useful than heritability alone in predicting the resultant effect on selecting best individuals. In the present investigation, expected genetic advance expressed as percentage of mean was high for straw yield per plant (31.66%), followed by dry matter content (31.56%), protein content in seed (30.88%), biological yield (28.95%) and number of pods per plant (26.05%).High heritability coupled with high genetic advance was observed for the above characters indicating that these characters are governed by additive gene action, hence there lies a good chance of improvement in these traits through direct selection in the present material. Similar findings were reported by Datta and Chatterjee (2004) Naik (2012). Narolia *et.al.* (2017)

Correlation and Path Studies

The estimates of genotypic correlation coefficient were higher than their corresponding phenotypic correlation coefficient values for most of the characters under study (Table 2 and 3). Phenotypic and Genotypic level envisaged that biological yield was having significant and positive correlation with chlorophyll content of the leaves, number of pods per plant, straw yield per plant, 1000 seed weight, dry matter content of the plant as whole and seed yield per plant while negatively correlated with the harvest index. However, biological yield per plant too showed positive and significant correlation with plant height and number of branches per plant only at genotypic level. Similar associations were observed for straw yield per plant, number of pods per plant which too exhibited positive and significant correlation with number of branches per plant, chlorophyll content, straw yield per plant, 1000 seed weight, dry matter content and seed yield per plant, however it was negatively and significantly correlated to harvest index. Number of seeds per pod was positively and significantly associated to dry weight during flower initiation, pod length, protein content and seed yield per plant. Pod length enjoyed a significant and positive correlation with protein content, plant height, dry weight at flowering phase, 1000 seed weight, dry matter content, harvest index and seed yield per plant at genotypic level. Protein content in the seed, too exhibited positive and significant association with number of branches per plant , number of seeds per pod at both phenotypic and genotypic level. Plant height was having positive association with 1000 seed weight, dry matter content, seed yield per plant in a significant manner both at phenotypic and genotypic level. Genotypic path analysis (Table 4) of the different characters revealed that biological yield had highest positive direct effect on seed yield per plant followed by harvest index, dry matter content, chlorophyll content in leaves, number of seeds per pod, dry weight at flower initiation, number of pods per plant, 1000 seed weight and number of branches per plant. The straw yield per plant and pod length had the highest negative direct effect on seed yield followed by days to 50% flowering, plant height and protein content in seed. Phenotypic path analysis (Table 5) of the different characters revealed that biological yield per plant had highest positive direct effect on seed yield per plant followed by harvest index, dry weight at flower initiation, chlorophyll content in leaves, number of branches per plant and 1000 seed weight. Straw yield per plant and plant height

Table 1. Genetic parameter of yield and yield attributing characters in fenugreek genotypes

Character	Mean	Range		PCV%	GCV%	Heritability (BS) %	Genetic Advance	Genetic advance as percentage of mean
		Min.	Max.					
Plant height (cm)	65.91	46.20	74.83	9.89	8.74	78.2	10.50	15.93
No. of branches/plant	14.60	11.23	16.20	10.99	6.42	34.2	1.13	7.73
Dry weight at flower initiation(g)	3.86	2.23	5.27	22.56	21.36	89.7	1.61	14.70
Chlorophyll content in leaves (SPAD Unit)	54.11	45.47	59.47	7.19	6.71	87.1	6.98	12.89
No. of pods/plant	66.74	51.10	80.14	13.08	12.86	96.7	17.39	26.05
No. of seeds / pod	15.50	13.86	17.47	7.32	5.92	65.4	1.53	9.87
Pod length (cm)	11.12	9.82	12.19	7.10	3.51	24.4	0.40	3.59
Biological yield/plant (g)	37.13	26.20	46.83	17.97	15.89	78.2	10.75	28.95
Straw yield per plant (gm)	24.92	13.50	33.62	21.63	18.23	71.0	7.89	31.66
Protein content in seed (%)	18.91	14.03	25.53	15.46	15.23	96.9	5.84	30.88
Days to 50% flowering	48.41	43.67	53.33	5.19	4.32	69.4	3.56	7.35
1000 seed wt (g)	14.41	11.10	19.10	14.08	12.97	84.8	3.55	24.63
Dry matter content (g)	56.48	39.53	75.23	19.06	17.09	80.4	17.83	31.56
Harvest index	34.19	27.89	50.24	16.16	12.32	58.1	6.62	19.36
Seed yield /plant(g)	12.49	9.77	17.03	16.02	13.30	68.9	2.84	22.73

Table 2. Genotypic correlation coefficient of yield and its component characters of fenugreek

Characters	Plant height (cm)	No. of branches/ plant	Dry wt at flower initiation (g)	Chlorophyll content (SPAD Unit)	No. of pods/ plant	No. of seeds/ Pod	Pod length (cm)	Biological yield/plant(g)	Straw yield/ plant (g)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index	Seed yield /plant (g)
Plant height (cm)		-0.049	0.283	0.413*	0.286	0.196	0.607**	0.430*	0.337*	0.101	-0.150	0.683**	0.588**	-0.177	0.413*
No. of branches/ plant			-0.153	0.594**	0.592**	0.272	-0.052	0.456**	0.449**	0.653**	-0.247	0.509**	0.160	-0.060	0.515**
Dry wt at flo. initiation (g)				0.069	0.240	0.482**	0.580**	0.200	0.161	0.241	0.017	0.300	0.253	-0.008	0.288
Chlorophyll (SPAD Unit)					0.380*	-0.147	0.031	0.518**	0.527**	0.181	-0.106	0.581**	0.207	-0.293	0.420*
No. of pods/plant						0.321	0.161	0.850**	0.826**	0.318	-0.169	0.375*	0.538**	-0.428*	0.680**
No. of seeds/pod							0.773**	0.215	0.089	0.567**	-0.086	0.386*	0.400*	0.226	0.483**
Pod length (cm)								0.248	0.056	0.445**	-0.300	0.462**	0.674**	0.356*	0.646**
Biological yield/p (g)									0.969**	0.213	-0.167	0.609**	0.749**	-0.607**	0.741**
Straw yield per plant (gm)										0.096	-0.041	0.532**	0.632**	-0.755**	0.575**
Protein content in seed (%)											-0.073	0.275	0.448**	0.329	0.550**
Days to 50% flowering												-0.433**	-0.314	-0.411*	-0.572**
1000 seed wt (g)													0.522**	-0.105	0.690**
Dry matter content (g)														-0.193	0.759**
Harvest index															0.073
Seed yield /plant(g)															

** 1% level of significance * 5% level of significance

Table 3. Phenotypic correlation coefficient of yield and its component characters of fenugreek

Characters	Plant height (cm)	No. of branches/ plant	Dry wt. at flower initiation (g)	Chlorophyll (SPAD Unit)	No. of pods/ plant	No. of seeds/ Pod	Pod length (cm)	Biological yield/plant(g)	Straw yield per plant (gm)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index	Seed yield /plant (g)
Plant height (cm)		0.011	0.219	0.341*	0.235	0.123	0.270	0.326	0.217	0.097	-0.093	0.558**	0.486**	-0.108	0.297
No. of branches/ plant			-0.077	0.265	0.355*	0.030	-0.046	0.285	0.207	0.379*	-0.023	0.268	0.184	0.032	0.401*
Dry wt at flo. initiation (g)				0.063	0.220	0.407*	0.310	0.162	0.118	0.224	0.027	0.252	0.207	0.031	0.258
Chlorophyll (SPAD Unit)					0.351*	-0.106	-0.049	0.419*	0.411*	0.167	-0.047	0.512**	0.192	-0.039	0.289
No. of pods/plant						0.196	0.071	0.770**	0.713**	0.310	-0.152	0.351*	0.487**	-0.356*	0.560**
No. of seeds/pod							0.390*	0.128	0.006	0.455**	-0.169	0.223	0.279	0.196	0.371*
Pod length (cm)								0.063	-0.035	0.211	-0.171	0.167	0.272	0.231	0.304
Biological yield/p (g)									0.953**	0.189	-0.106	0.479**	0.634**	-0.573**	0.623**
Straw yield per plant (gm)										0.086	-0.022	0.398*	0.494**	-0.750**	0.385*
Protein content in seed (%)											-0.051	0.254	0.399*	0.232	0.437**
Days to 50% flowering												-0.353*	-0.218	-0.265	-0.375*
1000 seed wt (g)													0.419*	-0.096	0.498**
Dry matter content (g)														-0.013	0.639**
Harvest index															0.263
Seed yield /plant(g)															

** 1% level of significance * 5% level of significance

Table 4. Genotypic path coefficient of yield and its component characters of fenugreek (Dependable variable-seed yield per plant)

Characters	Plant height (cm)	No. of branches/ plant	Dry wt. at flower initiation (g)	Chloro phyll (SPAD Unit)	No. of pods/ plant	No. of seeds/ Pod	Pod length (cm)	Biological yield/plant (g)	Straw yield per plant (g)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index
Plant height (cm)	-0.059	0.000	0.032	0.173	0.012	0.033	-0.145	0.792**	-0.366*	-0.006	0.013	0.007	0.166	-0.088
No. of branches/ plant	0.003	0.000	-0.017	0.103	0.026	0.046	0. 012	0.839**	-0.489**	-0.036	0.021	0.006	0.032	-0.030
Dry wt. at flo. initiation (g)	-0.017	0.000	0.112	0.012	0.010	0.082	-0.139	0.367*	-0.175	-0.013	0.001	0.003	0.050	-0.004
Chlorophyll (SPAD Unit)	-0.024	0.000	0.008	0.173	0.016	-0.025	-0.007	0.954**	-0.574**	-0.010	-0.009	0.006	0.041	-0.146
No. of pods/plant	-0.017	0.000	0.027	0.066	0.043	0.039	-0.039	1.566**	-0.900**	-0.017	0.014	0.004	0.106	-0.213
No. of seeds/pod	-0.011	0.000	0.054	-0.025	0.010	0.171	-0.185	0.395*	-0.096	-0.031	0.007	0.004	0.079	0.112
Pod length (cm)	-0.036	0.000	0.065	0.005	0.007	0.132	-0.239	0.456**	-0.061	-0.024	0.025	0.005	0.133	0.177
Biological yield/p (g)	-0.025	0.000	0.022	0.090	0.337*	0.037	-0.059	1.841**	-1.055**	-0.012	0.014	0.007	0.148	-0.302
Straw yield per plant (gm)	-0.020	0.000	0.018	0.091	0.036	0.015	-0.013	1.785**	-1.089**	-0.005	0.003	0.006	0.125	-0.376*
Protein content in seed (%)	-0.006	0.000	0.027	0.031	0.014	0.097	-0.106	0.392*	-0.104	-0.055	0.006	0.003	0.088	0.164
Days to 50% flowering	0.009	0.000	0.002	-0.018	-0.007	-0.015	0.072	-0.308	0.044	0.004	-0.084	-0.005	-0.062	-0.205
1000 seed wt (g)	-0.040	0.000	0.034	0.101	0.016	0.066	-0.111	1.121**	-0.579**	-0.015	0.036	0.011	0.103	-0.052
Dry matter content (g)	-0.034	0.000	0.028	0.036	0.026	0.068	-0.161	1.379**	-0.688**	-0.024	0.026	0.006	0.197	-0.096
Harvest index	0.010	0.000	-0.001	-0.051	-0.018	0.039	-0.085	-1.117**	0.822**	-0.018	0.034	-0.001	-0.038	0.498**

** 1% level of significance * 5% level of significance

Table 5. Phenotypic path coefficient of yield and its component characters of fenugreek (Dependable variable-seed yield per plant)

Characters	Plant height (cm)	No. of branche s/ plant	Dry wt. at flower initiation (g)	Chlorop hyll (SPAD Unit)	No. of pods/ plant	No. of seeds/ Pod	Pod length (cm)	Biologic al yield/pla nt(g)	Straw yield per plant (gm)	Protein content in seed (%)	Days to 50% flowering	1000 seed wt (g)	Dry matter content (g)	Harvest index
Plant height (cm)	-0.079	0.000	0.014	0.017	-0.004	0.000	0.004	0.583**	-0.189	-0.001	0.003	0.018	-0.004	-0.067
No. of branches/ plant	-0.001	0.046	-0.005	0.013	-0.006	0.000	-0.001	0.511**	-0.181	-0.003	0.001	0.009	-0.002	0.020
Dry wt. flower initiation (g)	-0.017	-0.004	0.064	0.003	-0.004	0.001	0.005	0.290	-0.103	-0.002	-0.001	0.008	-0.002	0.019
Chlorophyll (SPAD Unit)	-0.027	0.012	0.004	0.049	-0.006	0.000	-0.001	0.749**	-0359*	-0.001	0.002	0.017	-0.002	-0.148
No. of pods/plant	-0.019	0.016	0.014	0.017	-0.017	0.000	0.001	1.379*	-0.623**	-0.002	0.005	0.012	-0.004	-0.220
No. of seeds/pod	-0.010	0.001	0.026	-0.005	-0.003	0.002	0.006	0.230	-0.005	-0.003	0.006	0.007	-0.002	0.121
Pod length (cm)	-0.021	-0.002	0.020	-0.002	-0.001	0.001	0.017	0.113	0.031	-0.002	0.006	0.006	-0.002	0.143
Biological yield/plant(g)	-0.026	0.013	0.010	0.021	-0.013	0.000	0.001	1.790**	-0.832**	-0.001	0.004	0.016	-0.006	-0.353
Straw yield per plant (gm)	-0.017	0.009	0.008	0.020	-0.012	0.000	-0.001	1.705**	-0.874**	-0.001	0.001	0.013	-0.004	-0.463
Protein content in seed (%)	-0.008	0.017	0.014	0.028	-0.005	0.001	0.004	0.338*	-0.075	-0.007	0.002	0.008	-0.004	0.143
Days to 50% flowering	0.007	-0.001	0.020	-0.020	0.003	0.000	-0.003	-0.190	0.109	0.000	-0.035	-0.012	0.002	-0.164
1000 seed wt (g)	-0.044	0.012	0.016	0.025	-0.006	0.001	0.003	0.858**	-0.348*	-0.002	0.013	0.033	-0.004	-0.059
Dry matter content (g)	-0.039	0.008	0.013	0.029	-0.008	0.001	0.005	1.136**	-0.432**	-0.003	0.008	0.014	-0.009	-0.064
Harvest index	0.009	0.001	0.020	-0.012	0.006	0.000	0.004	-1.025**	0.655**	-0.002	0.009	-0.003	0.001	0.617**

** 1% level of significance * 5% level of significance

had the highest negative direct effect on seed yield. Traits like straw yield per plant and plant height imparted negative direct effect on seed yield per plant. Thus, for increasing seed yield per plant d emphasis on traits having positive and direct effect should be given due importance and balanced selection based on these traits would be more rewarding for improvement of fenugreek. Similar observations have been cited by scientists like Dashora *et al.* (2011), Naik *et al.* (2011) Fikreselassie *et al.* (2012) and Kumar *et.al.* (2018)

References

Banerjee, A. and Kole, P. C. 2004. Genetic variability, correlation and path analysis in fenugreek. *Journal of Spices Aromatic Crops*, 13 (1): 44-48.

Burton, G. W. 1952. Quantitative inheritance in grasses. *Proc. Sixth Inter. Grassland Cong.*, 1: 227-283.

Dashora, A., Maloo, S. R. and Dashora, L. K. 2011. Variability, correlation and path coefficient analysis in fenugreek (*Trigonella foenum-graecum* L.) under water limited conditions. *Journal of Spices and Aromatic Crops*, 20 (1): 38-42.

Datta, S. and Chatterjee, R. 2004. Performance of fenugreek genotypes under new alluvial zone of West Bengal. *Journal of Spices and Aromatic Crops*, 13 (2): 13-24.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.*, 51: 51-58.

Fikreselassie, Million, Zeleke, H. and Alemayehu, Nigussie. 2012. Genetic variability of Ethiopian fenugreek (Trigonella foenum graecum L.) landraces. *Journal of Plant Breeding and Crop Science*, 4 (3): 39-48.

Gangopadhyay, K. K., Yadav, S. K., Kumar, G., Meena, B. L., Mahajan, R. K., Mishra, S. K. and Sharma, S. K. 2009. Correlation, path-coefficient and genetic diversity pattern in fenugreek. *Indian Journal of Agricultural Science*, 79 (7): 521-526.

Hanson, C. H., Robinson, H. F. and Comstock, R. E. 1956. Biometrical studies of yield in segregating populations of Korean, Lespedize. *Agronomy Journal*, 48: 268-272.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybeans. *Agron. J.*, 47: 31-48.

Pandey, Kumar, Aman, Maurya, V.P.,Tiwari, Vipin Kumar, Tiwari, Devesh and Sriom 2018. Genetic variability, heritability & genetic advance in fenugreek (*Trigonella foenum-graecum* L.) *International Journal of Chemical Studies*, 6(4): 153-156.

Meena, R. S., Kakani, R. K., Anwer, M. M., Panwar, A., Choudhary, S. and Meena, S.R. 2011. Variability studies in fenugreek (*Trigonella foenum-graecum* L.) *International J. Seed Spices*, 1 (1): 44-6.

NHB. 2012. Indian Horticulture Data base-2013, Ministry of Agriculture, Government of India 85, Institutional Area, Sector18, Gurgoan-122015, pp 202-205.

Naik, A., Akhtar, S., Bhuniam, P. and Pandey, V. P. 2011. Correlation coefficient and path analysis studies in fenugreek (*Trigonella foenum-graecum* L.). *Environment and Ecology*, 29: 3B, 1 546-1549.

Naik, Abhishek. 2012. Characterization fenugreek (*Trigonella foenum-graecum* L.) genotypes through morphological characters. *Intl. J. Agric. Env. Biotech.*, 5(4): 453-457.

Narolia, S. L., Meena, M. L. , Atal, M. K. and Verma, Niharika. 2017. Genetic variability, heritability and genetic advance in Fenugreek (Trigonella foenum-graecum L.) Genotypes *Int. J. Pure App. Bio Sci.*, 5 (6): 452-458.

Panes, V. G. and Sukhatme, P. V. 1985. Statistical Method for Agriculture Workers. Indian Council of Agriculture Research, New Delhi, 155.

Prajapati, D. B., Ravindrababu, Y. and Prajapati, B. H. 2010. Genetic variability and haracter association in fenugreek *(Trigonella foenum-graecum* L.). *Journal of Spices and Aromatic Crops*, 19 (1&2): 61-64.

Sharma, K. C. and Sastry, E. V. D. 2008. Path analysis for seed yield and its component characters in fenugreek *(Trigonella foenum-graecum* L.). *Journal of Spices and Aromatic Crops*, 17 (2): 69-74.

Wright, S. 1921. Correlation and causation *J. Agric. Res.*, 20: 557-587.

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Effect of potassium and zinc on growth, yield and quality of garlic (*Allium sativum* L.)

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Abstract

A field experiment was conducted during *Rabi* season 2017-18 at the Research Farm, College of Horticulture, Mandsaur (M.P.) to study the response of potassium and zinc on growth, yield and quality of garlic. The experiment was laid out in factorial RBD design with three replications including four levels of potassium (0, 25, 50 and 75 kg K_2O/ha) and three levels of zinc (0, 5 and 10 kg Zn/ha). Results showed that application of K_3Z_2 (75 Kg K_2O/ha + 10 Kg Zn/ha) significantly increased the plant height, number of leaves per plant, fresh weight of plant (g), dry weight of plant (g) fresh weight of bulb (32.4g), dry weight of bulb (10.22 g), polar diameter of bulb (4.73 cm), equatorial diameter of bulb (4.72 cm), bulb yield (146.7 q/ha), volatile oil content in bulb (0.40%) and non-significant effect showed in TSS content in bulb (42.51 ^{0}Brix). Therefore, the application of 75 Kg K_2O/ha and 10 Kg Zn/ha gave maximum growth, yield and quality attributes and of garlic.

Keywords: Garlic, potassium, zinc, growth, volatile oil

Introduction

Garlic (*Allium sativum* L.) is one of the important spice crop belong to family Alliaceae. The bulb is tunicate and is composed of disc-like stem, thin dry scales, which are the bases of the foliage leaves and smaller bulbs or cloves. The cloves are enclosed by the dry outer scales having cloves consist of a protective cylindrical sheath, a single thickened storage leaf sheath and small central bud (Farooqi *et al.*, 2004). Potassium plays an important role in maintenance of cell water potential because it regulates opening and closing of stomata (Sinha, 1978), Biebl (1958) reported that potassium facilitates water uptake by plants from the soil solution is regulate by several factors including soil texture, moisture conditions, pH, aeration and temperature (Mengel and Kirkby, 1980).

Zinc is essential component and activator of many enzymes involved in auxin biosynthesis and photosynthesis (Romheld and Marscher, 1991) and their act as an important role in plant growth and yield of garlic. Zinc is most deficient among all the micronutrients in Indian soils condition. In many parts of India, zinc as a plant nutrient now stands third in importance next to nitrogen and phosphorus (Takkar and Randhawa, 1980). It plays an important role as a constituent of alcohol dehydrogenase and carbonic anhydrase in both microorganisms an higher plants. It helps the utilization of phosphorus and nitrogen in plants (Singh *et al.*, 2002).

Materials and Methods

The experiment was laid out at the "Research Field of the Department of Plantation, Spices, Medicinal and Aromatic Crops", College of Horticulture, Mandsaur, RVSKVV, Gwalior, (M.P.) during *Rabi* season of 2017-18. Mandsaur is situated in Malwa Plateau in western part of Madhya Pradesh at North latitude of 23.45° to 24.13° and 74.44° to 75.18° East longitudes and an altitude of 435.02 meters above mean sea level. The soil of the experimental field was light black loamy in texture with low nitrogen (192 kg/ha), low phosphorus (7.6 kg/ha), medium potassium (145.0 kg/ha) soil having (pH 8.36) and EC (0.18 dS/m). The field experiment comprising 12 treatment combinations with the three replications was laid out in factorial randomized block design with two factors. The experiment consisted of four levels of potassium (0, 25, 50 and 75 kg K_2O/ha) and three levels of zinc (0, 5 and 10 kg Zn/ha). The crop variety G-282 were sown in spacing 15x10 cm with seed rate of 500 kg/ha. Uniform dose of nitrogen (150 kg/ha) through urea and phosphorus (60 kg/ha), through single super phosphate, potash and zinc nutrient were applied according to the treatment. Data were recorded for various growth, yield and quality parameters and statistically analyzed using the method of analysis of variance as described by Panse and Sukhatme (1985).

Results and Discussion

Effect of Potassium on growth attributes

Maximum plant height (30.84, 50.50, 71.13, 73.23 cm) at 30, 60, 90 and 120 DAS, number of leaves (3.87, 6.58, 8.71, 9.49) per plant at 30, 60, 90 and 120 DAS, fresh weight (2.72, 8.55, 28.57, 67.00 g) of plant (g) at 30, 60, 90 and 120 DAS, dry weight (0.53, 2.61, 7.08, 30.14, 28.13 g) of plant (g) at 30, 60, 90, 120 DAS and at harvest were recorded under application of potassium K_3 (75 kg K_2O ha^{-1}) followed by K_2

(50 kg K_2O ha^{-1}) and lowest in K_0 (0 kg K_2O ha^{-1}) at all the growth stages. It may be attributed to the fact that application of potassium improved not only availability of potassium but other nutrients also which are considered vitally important for growth and development of plants. The similar results have also been reported by Magray *et al.* (2017), Ismail *et al.* (2014), Arisha *et al.* (2017), Sayed *et al.* (2012), Sakarvadia *et al.* (2009) in garlic and Aftab *et al.* (2017) in onion.

Effect of Potassium on Yield attributes

Maximum fresh weight (28.5 g) of bulb, dry weight (9.57 g) of bulb, polar diameter (4.72 cm), equatorial diameter (4.42 cm) and bulb yield (139.3 q/ha) were recorded under application of potassium in K_3 (75 kg K_2O ha^{-1}) followed by K_2 (50 kg K_2O ha^{-1}) and lowest in K_0 (0 kg K_2O ha^{-1}) at all the stages of yield attributes. The similar results have also been reported by Sayed *et al.* (2012), Magray *et al.* (2017), Ismail *et al.* (2014), Arisha *et al.* (2017), Sakarvadia *et al.* (2009) in garlic and Aftab *et al.* (2017) in onion.

Effect of Potassium on quality attributes

Maximum TSS (41.63 ^{0}Brix) content and oil content (0.33 %) were recorded under application of potassium levels in K_3 (75 kg K_2O ha^{-1}) followed by K_2 (50 kg K_2O ha^{-1}) and lowest in K_0 (0 kg K_2O ha^{-1}). These may be due to potassium is essential for production of oil and fats. Similar results were also reported by Sayed *et al.* (2012), Arisha *et al.* (2017), Ismail *et al.* (2014) in garlic and Desuki *et al.* (2006) and Verma and singh (2012) in onion.

Potassium plays an important role in maintenance of cell water potential because it regulates opening and closing of stomata (Sinha, 1978). Biebl, 1958 reported that potassium facilitates water uptake by roots and reduces transpiration loss in plant.

Effect of zinc on growth attributes

Maximum plant height (30.44, 50.73, 71.22, 72.60cm) at 30, 60, 90 and 120 DAS , number of leaves (3.82, 6.48, 8.50, 9.34) per plant at 30, 60, 90 and 120 DAS, fresh weight (2.50, 7.65, 28.34, 64.46) of plant (g) at 30, 60, 90 and 120 DAS, dry weight (0.53, 2.65, 6.27, 26.91, 27.28) of plant (g) 30, 60, 90, 120 DAS and at harvest, were recorded under application of zinc Z_2 (10 kg Zn ha^{-1}) followed by Z_1 (5 kg Zn ha^{-1}) and lowest in Z_0 (0 kg Zn ha^{-1}) at all the growth stages. It might be due to better growth and development of plant parts in terms of plant height, no. of leaves. Application of zinc might have increased the availability and steady supply of nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development of the crop. In addition, zinc is important in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxins) like Indol-Acetic Acid. Such improvement under increased availability of zinc in rhizosphere might have resulted in greater uptake by the plant consequently leading to a favourable effect on various processes of plant".

The similar results have also been reported by Rohidas *et al.* (2010), Chanchan *et al.* (2014), Islam *et al.* (2012), Sakarvadia *et al.* (2009) in garlic and Manna *et al.* (2014) in onion.

Effect of Zinc on Yield and yield attributes

Maximum fresh weight (28.8 g) of bulb, dry weight (9.32 g) of bulb, polar diameter (4.51 cm), equatorial diameter (4.31 cm) and bulb yield (136.7 q/ha) were recorded under application of zinc Z_2 (10 kg Zn ha^{-1}) followed by Z_1 (5 kg Zn ha^{-1}) and lowest in Z_0 (0 kg Zn ha^{-1}) at all thestages of yield attributes. Similar results were also reported by Chanchan *et al.* (2014), Rohidas *et al.* (2010), Islam *et al.* (2012), Nasreen *et al.* (2009) In garlic and Manna *et al.* (2014) and Trivedi and Dhumal (2013) in onion.

Effect of Zinc on quality attributes

Maximum TSS content (38.25 ^{0}Brix) in bulb and volatile oil content (0.32 %) in bulb were recorded under application of zinc Z_2 (10 kg Zn ha^{-1}) followed by Z_1 (5 kg Zn

Table 1. Effect of potassium and zinc on growth and yield of garlic

Treat.	Plant height (cm)				No of leaves per plant				Fresh weight of plant (g)				Dry weight of plant (g)				
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Potassium																	
K_0	26.16	47.77	65.76	66.58	3.32	5.06	7.37	8.00	2.03	4.41	22.93	53.01	0.42	1.35	4.49	18.46	22.13
K_1	29.90	49.52	67.91	67.52	3.49	6.44	7.66	8.42	2.24	6.34	25.40	58.66	0.47	2.68	5.69	24.95	24.97
K_2	30.32	50.27	69.84	69.57	3.50	6.57	8.33	8.82	2.39	6.86	25.62	63.76	0.48	2.42	6.42	27.63	26.59
K_3	30.84	50.50	71.13	73.23	3.87	6.58	8.71	9.49	2.72	8.55	28.57	67.00	0.53	2.61	7.08	30.14	28.13
SEm±	0.36	0.42	0.72	1.52	0.09	0.10	0.15	0.18	0.12	0.32	0.61	1.11	0.02	0.07	0.10	0.31	0.37
CDat 5%	1.06	1.23	2.11	4.46	0.26	0.28	0.43	0.54	0.34	0.95	1.78	3.27	0.05	0.22	0.30	0.92	1.09
Zinc																	
Z_0	28.05	47.41	64.06	64.63	3.31	5.66	7.48	7.82	2.00	5.08	22.31	53.27	0.41	1.81	5.54	23.74	22.73
Z_1	29.43	50.41	70.71	70.45	3.51	6.35	8.07	8.89	2.53	6.89	26.24	64.09	0.49	2.34	5.95	25.24	26.36
Z_2	30.44	50.73	71.22	72.60	3.82	6.48	8.50	9.34	2.50	7.65	28.34	64.46	0.53	2.65	6.27	26.91	27.28
SEm±	0.31	0.36	0.62	1.32	0.08	0.08	0.13	0.16	0.10	0.28	0.53	0.96	0.02	0.06	0.09	0.27	0.32
CD at 5%	0.91	1.07	1.82	3.86	0.22	0.24	0.37	0.47	0.30	0.82	1.54	2.83	0.05	0.19	0.26	0.80	0.94

Table 2. Effect of potassium and on growth, yield and quality of garlic

Tret.	Fresh weight of bulb (g)	Dry weight of bulb (g)	Polar diameter(cm)	Equatorial diameter (cm)	Bulb yield (q ha^{-1})	TSS conten t (^{0}Brix)	Volatile oil content (%)
Potassium							
K_0	23.3	8.40	3.94	3.63	114.6	33.28	0.22
K_1	26.7	8.66	4.33	4.10	131.1	36.20	0.26
K_2	27.0	9.12	4.50	4.36	134.8	38.83	0.31
K_3	28.5	9.57	4.72	4.42	139.3	41.63	0.33
SEm±	0.58	0.07	0.05	0.06	0.52	0.18	0.01
CD at 5%	1.70	0.20	0.14	0.17	1.53	0.54	0.02
Zinc							
Z_0	23.1	8.49	4.19	3.96	118.7	36.64	0.23
Z_1	27.2	9.00	4.43	4.11	133.3	37.57	0.29
Z_2	28.8	9.32	4.51	4.31	136.7	38.25	0.32
SEm±	0.50	0.06	0.04	0.05	0.45	0.16	0.01
CDat 5%	1.47	0.17	0.12	0.15	1.33	0.47	0.02

Table 3. Combined effect of potassium and zinc on growth parameter of garlic.

Treatment	Plant height (cm)				No of leaves per plant				Fresh weight of plant (g)			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
K_0Z_0	23.17	46.50	63.33	62.90	3.07	5.00	7.07	7.50	1.76	3.91	21.97	51.87
K_0Z_1	27.01	48.20	66.17	66.60	3.17	5.02	7.10	8.10	2.00	4.26	23.10	54.82
K_0Z_2	28.30	48.37	67.20	68.00	3.73	5.17	7.20	8.40	2.33	5.07	23.73	52.33
K_1Z_0	28.87	49.33	64.33	65.30	3.47	5.67	7.80	7.83	2.08	5.77	22.20	51.11
K_1Z_1	29.61	51.50	70.13	70.80	3.37	6.73	7.93	8.63	2.55	6.20	26.07	62.42
K_1Z_2	30.13	50.67	69.27	69.27	3.67	6.74	7.97	8.80	2.11	7.03	27.93	62.44
K_2Z_0	30.15	47.07	63.39	65.13	3.23	5.97	7.77	8.10	2.10	4.86	22.37	55.33
K_2Z_1	30.33	50.40	73.33	70.27	3.60	6.73	8.30	8.87	2.80	7.35	25.67	68.89
K_2Z_2	30.48	51.10	72.87	69.40	3.63	6.82	8.83	9.50	2.28	8.37	28.83	67.06
K_3Z_0	30.00	46.73	64.67	65.17	3.47	6.00	8.00	7.83	2.07	5.77	22.70	54.77
K_3Z_1	30.77	51.53	73.20	74.13	3.90	6.83	8.93	9.97	2.80	9.77	30.13	70.22
K_3Z_2	31.75	52.77	75.53	83.73	4.23	7.00	9.30	10.67	3.29	10.13	32.87	76.00
SEm±	0.62	0.73	1.24	2.63	0.15	0.17	0.25	0.32	0.20	0.56	1.05	1.19
CD at 5%	1.83	2.14	3.65	7.72	NS	0.49	NS	0.93	NS	1.64	3.09	5.85

Table. 4. Combined effect of potassium and zinc on yield and quality parameter of garlic.

Treatment	Dry weight of plant (g)					Fresh weight of bulb (g)	Dry weight of bulb (g)	Polar diameter of bulb (cm)	Equatorial diameter of bulb (cm)	Bulb yield (q\ha)	TSS content in bulb (^{0}Brix)	Volatile oil content in bulb (%)
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest							
K_0Z_0	0.40	1.29	4.26	17.44	21.07	1.76	3.91	21.97	51.87	0.40	32.61	0.21
K_0Z_1	0.41	1.33	4.44	18.59	22.47	2.00	4.26	23.10	54.82	0.41	33.30	0.21
K_0Z_2	0.44	1.42	4.77	19.36	22.87	2.33	5.07	23.73	52.33	0.44	33.92	0.23
K_1Z_0	0.40	2.51	4.89	21.96	22.77	2.08	5.77	22.20	51.11	0.40	35.19	0.26
K_1Z_1	0.49	2.76	6.04	25.26	25.47	2.55	6.20	26.07	62.42	0.49	36.64	0.33
K_1Z_2	0.53	2.78	6.14	27.63	26.67	2.11	7.03	27.93	62.44	0.53	36.78	0.34
K_2Z_0	0.42	1.68	6.52	26.55	23.33	2.10	4.86	22.37	55.33	0.42	37.81	0.23
K_2Z_1	0.49	2.51	6.22	26.66	27.77	2.80	7.35	25.67	68.89	0.49	38.88	0.24
K_2Z_2	0.54	3.08	6.51	29.67	28.67	2.28	8.37	28.83	67.06	0.54	39.81	0.32
K_3Z_0	0.41	1.77	6.49	29.00	23.73	2.07	5.77	22.70	54.77	0.41	40.95	0.24
K_3Z_1	0.57	2.77	7.12	30.45	29.73	2.80	9.77	30.13	70.22	0.57	41.45	0.36
K_3Z_2	0.60	3.30	7.65	30.99	30.93	3.29	10.13	32.87	76.00	0.60	42.51	0.40
SEm±	0.03	0.13	0.18	0.54	0.64	0.20	0.56	1.05	1.19	0.03	0.32	0.10
CDat 5%	NS	0.38	0.52	1.6	1.89	NS	1.64	3.09	5.85	NS	NS	0.40

ha^{-1}) and lowest in Z_0 (0 kg Zn ha^{-1}). The increased in volatile oil content of garlic due to application of zinc has also been reported by Hatwal *et al.* (2015), Manna *et al.* (2014) Trivedi and Dhumal (2013) in onion.

Interaction effect of potassium and zinc

Combined effect of potassium and zinc exerted significantly influence on growth attributes *viz.*, plant height, number of leaves per plant, fresh weight and dry weight of plant (g), at all the growth stages except number of leaves per plant, fresh weight dry weight at 30 DAS. Maximum plant height, number of leaves per plant, fresh weight and dry weight of plant (g), were recorded under treatment combination K_3Z_2. Minimum plant height, number of leaves per plant, fresh weight and dry weight of plant (g) were recorded under K_0Z_0. Similar results were also reported by Sakarvadia *et al.* (2009) in garlic.

Combined effect of potassium and zinc showed significantly influence on yield attributes *viz.*, Maximum fresh weight of bulb (g), dry weight of bulb (g), polar diameter of bulb (cm), equatorial diameter of bulb (cm) and bulb yield (q ha^{-1}) were recorded under treatment combination K_3Z_2. Minimum fresh weight of bulb (g), dry weight of bulb (g), polar diameter of bulb (cm), equatorial diameter of bulb (cm), number of cloves per bulb and bulb yield (q ha^{-1}) were recorded under treatment combination K_0Z_0.

Combined effect of potassium and zinc showed significantly influence on quality attributes *viz.*, TSS content in bulb (^{0}Brix) and volatile oil content in bulb (%). Maximum amount of TSS content in bulb (^{0}Brix) and oil content in bulb (%) were recorded under treatment combination K_3Z_2. Minimum amount of TSS content in bulb (^{0}Brix) and oil content in bulb (%) were recorded under treatment combination K_0Z_0 in garlic.

On the basis of one year research it could be concluded that application of potassium and zinc influence the growth, yield and quality of garlic. The growth, yield and quality of garlic can be increased by application of K_3Z_2 (75 Kg K_2O/ha + 10 Kg Zn/ha) should be advocated for garlic.

References

Aftab, S., Hamid, F. S., Farrukh, S., Waheed, A., Ahmed, N., Khan, N., Ali, S., Bashir, M., Mumtaz, S., Gul, H., and Younis, M.A. 2017. Impact of Potassium on the Growth and Yield Contributing Attributes of Onion (*Allium cepa* L.).*Asian Research Journal of Agriculture,* 7(3): 1-4.

Arisha, H. M. E., Ibraheim, S. K. A., and El-Sarkassy, N. M. 2017. Response of Garlic (*Allium sativum* L.) Yield, Volatile Oil and Nitrate Content to Foliar and Soil Application of Potassium Fertilizer under Sandy Soil Conditions. *Middle East Journal of Applied Sciences*, 7(01): 44-56.

Beibl, R. 1958. Influence of K nutrition on the response to environmental stress. In. Potassium Research Review and Trends. *International Potash Institute Berne/Switzerland*, pp.189-222.

Chanchan, M. and Hore, J. K. 2014. Studies on the effect of micronutrients on growth and yield of garlic. *Research on Crops*, 15(3): 701-704.

Desuki- El, M., Abdel-Mouty, M. M., and Ali, A. H. 2006. Response of onion plants to additional dose of potassium application. *Journal of Applied Science Research*, 2(9): 592-597.

Farooqi, A. A., Sreeramu B. S. and Srinivaspa, K. N. 2004. Cultivation of spices crops. Universities press, pp-129-130.

Hatwal, P. K., Kavita, A., Choudhary, M. K. and Singh, B. 2015. Effect of vermicompost, sulphur and micronutrients on yield and quality of garlic (*Allium sativum* L.) var. 'G-282'. *Annals of Biology*, 31(1): 85-90.

Islam, M. A., Shamsuddoha, A. T. M., Bhuiyan, M. S. I. and Hasanuzzaman, M. 2008. Response of summer onion to potash and its application methods. *Amer-Euras J. Agron*, 1(1): 10-15.

Ismail, H. E. M., Bardisi, A. and El-Khair, E. E. A. 2014. Impact of potassium fertilization on growth, productivity and bulb quality of garlic plants. *Global Journal of Agriculture and Food Safety Sciences*, 1(2): 107-125.

Magray, M. M., Chattoo, M. A., Narayan, S. and Mir, S. A. 2017. Influence of Sulphur and Potassium Applications on Yield, Uptake & Economics of Production of Garlic. *Int. J. Pure App. Biosci*, 5(5): 924-934.

Manna, D., Maity, T. K. and Ghosal, A. 2014. Influence of foliar application of boron and zinc growth, yield and bulb quality of onion (*Allium cepa* L.). *Journal of Crop and Weed*, 10(1): 53-55.

Mengel, K. and Kirkby, E. A. 1980. Potassium in crop production. In *Advances in Agronomy,* 33: 59-110.

Nasreen, S., Yousuf, M. N., Mamun, A. N. M., Brahma, S. and Haquc, M. M. 2009. Response of garlic to zinc, boron and poultry manure application. *Bangladesh Journal of Agricultural Research*, 34(2): 239-245.

Pansey, V.G. and Sukhatme, P.V. 1985. Statistical Methods, for Agricultural Workers. Forth Enlarged Edition. *ICAR Publication*, New Delhi.

Rohidas, S. B., Bharadiya, P. S., Jature, S. D. and Ghate, K. B. 2010. Effect of micronutrient on growth and yield of garlic (*Allium sativum* L.) var. G-41. *Asian Journal of Horticulture*, 5(2): 517-519.

Romheld, V. and Marscher, H. 1991. Function of micronutrients in plants. (In) Mortredt J. (Eds.). Micronutrients in Agriculture No. 4, Soil Science Society of America, Madison, Wisconsin, pp. 277.

Sakarvadia, H. L., Polara, K. B., Parmar, K. B., Babariya, N. B. and Kunjadia, B. B. 2009. Effect of potassium and zinc on growth, yield and nutrient uptake by garlic. *An Asian Journal of Soil Science*, 4(1): 110-112.

Sayed- El-, H. E. A. and El-Morsy, A. H. A. 2012. Response of productivity and storability of garlic (*Allium sativum*

L.) to some potassium levels and foliar spray with mepiquat chloride (PIX). *International Research Journal of Agriculture and Soil Science*, 2(7): 298-305.

Singh.; Satpal., Jat, N.L. and Singh, S. 2002. Effect of zinc fertilizer on growth and yield of coriander. *Ann of Agri. Res.*, 23(4): 734-736.

Sinha, S.K. 1978. Influence of potassium on tolerance to stress. Indian experience. In. *Potassium in soil and crops* (Ed.). Sekhon, G.S., Potash Research Institute of India, Gurgaon, Haryana, India, pp. 223-240.

Takkar, P.N. and Randhawa, N.S. 1980. Zinc deficiency in Indian soils and plants. Seminar on zinc wastes and their utilization, 15-18, Oct. organized by Indian lead zinc information center anthe fertilizer Association of India, New Delhi.

Tondon, H.L.S.(1991. Sulphur research and agricultural production in India. pp. 477.

Trivedi, A. P. and Dhumal, K. N. 2013. Effect of soil and foliar applications of zinc and iron on the yield and quality of onion (*Allium cepa* L.). *Bangladesh Journal of Agricultural Research*, 38(1): 41-48.

Verma, D. and Singh, H. 2012. Response of varying levels of potassium and sulphur on yield and uptake of nutrients by onion. *Annals of Plant and Soil Research, Azadnaga*, 14(2): 143-146