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EFFECT OF WATER STRESS ON NUTRIENT CONTENT AND THEIR UPTAKE IN INDIAN MUSTARD[*Brassica juncea* (L.) Czern and Coss] GENOTYPES

Dr Chitta Ranjan Sahoo[1], Dr Manasi Dash[2] & Dr N. Acharya[2]

[1]Department of Plant Physiology, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, INDIA
[2]Department of Plant Breeding & Genetics, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, INDIA

ABSTRACT

The mustard crop, during its ontogeny, is observed to face the effect of moisture stress of various degrees, especially at different growth stages of crop leading to drastic reduction in production and productivity. Four varieties of Indian mustard viz., Pusa Bahar, Varuna, Pusa Jai Kisan and Pusa Agrani were used to study the biochemical response to water stress. Water stress was imposed by withholding irrigation at 3 different stages of crop growth i.e., vegetative (S_1), reproductive (S_2) and pod-filling (S_3) stage. The total chlorophyll content, nitrate reductase activity (NRA) and starch content decreased significantly in all the varieties irrespective of stress at different growth stages, the maximum reduction was observed at pod filling stage. The maximum impact of water stress on total chlorophyll content was observed at pod filling stage (35.68- 44.81%) among the cultivars. The total chlorophyll content decreased a maximum in cv. Pusa Agrani and minimum in Pusa Jai Kisan. Proline accumulation increased in all the test varities irrespective of stress at different growth stages, maximum accumulation was observed at reproductive stage. Cultivar Varuna registered the maximum prolin accumulation. Total chlorophyll and proline content can be considered as the desirable traits for screening the cultivars for drought prone environments.

Key words**:** Mustard, water stress, nitrase reductase activity, proline content, starch content.

1. INTRODUCTION

Water stress during the crop ontogeny has been one of the main constraints for sustainable mustard productivity, especially in rainfed mustard growing tracts. The varieties evolved so far have not been adequate to suit the varied agro-climatic situations so as to maximize the production thereof. The fact is crop losses vary depending upon the intensity and duration of drought, growth stage, the genotype and physiology of the crop species. The solution to overcome thus lies in either making water available for crop growth or breeding for water/moisture stress resistant cultivars. Improvements on crop water stress resistance are therefore sought through plant breeding. Cultivars with better ability to access soil water and improved water use efficiency could increase yields in an economic and environmentally sustainable way. Water deficit tolerance appears to be the result of co-ordination of morphological, physiological and biochemical alterations at the organ, cellular and molecular level leading to water stress resistance of crop plants (Reddy and Vanaja, 2006). Hence, consistency of performance despite the vagaries of climate, particularly rainfall and consequential, water availability, is an important selection criterion in breeding for drought, resistance (Lupton, 1980). Arnon (1980), therefore, advocated the use of widely adapted varieties in drought prone areas. However, the success in performance of adaptability of a variety would depend upon the specific environment in which a plant has to grow (Aggarwal *et al*., 1986). Hence, it is important to define the characteristics, which confer to a variety specific for wider adaptability and the environment under which it will be tested or grown. Improving the yield potential of an already resistant material may be a more promising strategy, provided there is genetic variation within such a material. Transfer of an improved traits to already otherwise adapted varieties can proceed simple by accumulating beneficial alleles (Rajaram *et al*., 1996). Such an approach should therefore; complement empirical programmes and hasten yield and quantity improvements. In this context, Sinha and Khanna (1996) suggested to combine drought resistance with high yielding genotypes of crop species. According to them simultaneous selection in non-stress environment for yield and in drought conditions for stability may be done to achieve the desired goal of evolving drought resistant genotypes with high yielding potential. The present study aimed at assessing the water stress resistance characteristics of rainfed mustards popularly grown under agro-climatic zones of coastal Orissa and to suggest desirable putative traits on breeding for water stress resistance vis-à-vis augmentation of mustard productivity.

2. MATERIALS AND METHODS

The experiment was conducted during rabi season in 2004-05 and 2005-06 with mustard and designed in factorial randomized block design (FRBD) at the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar ($20^0$15' North; $85^0$52' East; 25.9 m AMSL) located in zone-III agroclimatic zone of Orissa (India). The soil of the experimental site is well drained sandy loam in texture with pH of 6.3, organic carbon (0.36), total nitrogen (123 kg ha^{-1}), available P_2O_5 (9.3 kg ha^{-1}), and available K_2O (118 kg ha^{-1}). The crop was fertilized with 60, 30 and 40 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Other package of practices was followed as recommended for the place. Four varieties viz., Pusa Bahar, Varuna, Pusa Jai Kisan and Pusa Agrani were used in the experiment. Water stress was imposed by withholding irrigation at 3 different stages of crop growth i.e., vegetative (S_1), reproductive (S_2) and pod-filling (S_3) stage. The stress inductive cycle continued till incipient wilting of leaves. The field studies were conducted taking 16-

treatments combination (along with control, S_0) laidout in factorial randomized block design (FRBD) with three replications. Samples Seeds of 5 number of plant for each variety at a given water stress condition were prepared. The samples were kept in oven at 85 ^{0}C for 24 hr. to bring the moisture level approximately to same level. Then the samples were ground finely to the estimation of N, P, K and S. Total nitrogen content of the seed samples were estimated by the Kjeldahl digestion method following procedures of A.O.A.C. (1970). Phosphorus, potassium and sulphur content of seeds sample were estimated by adopting the procedure of AOAC (1970) and Jackson (1973). The uptake of each nutrient in seed was worked out by multiplying their nutrient content with corresponding treatment seed yield. The total nutrient uptake was computed by summing up the amounts removed in seed and was expressed in kg ha^{-1}. The data obtained were analysed statistically in a factorial randomized block design (FRBD) and tested at 5 per cent level of significance (Cochran and Cox, 1977).

3. RESULTS AND DISCUSSION

3.1 N – content and uptake

The results revealed that nitrogen content increased significantly when the plants were subjected to simulated water stress irrespective of varieties and growth stages of the crop. At vegetative stage Pusa Agrani registered the highest increase of 1.25% in N-content over its control closely followed by Varuna (1.23%) and Pusa Jai Kian (0.95%). At reproductive stage variety Pusa Agrani registered the highest increase of 1.86 % in N-content closely followed by Pusa Jai Kisan with 1.79 % increase and the least increase in N-content among the four was in case of Pusa Bahar (1.69%). When stress was applied at pod filling stage the greatest increase (1.54 %) in N-content was recorded in case of Agrani closely followed by Pusa Jai Kisan (1.50 %), Varuna (1.45 %) and Pusa Bahar (1.26 %) compared to control. The highest mean nitrogen content of 3.74% was registered by Varuna and the least of 3.48% was recorded in Pusa Bahar. Among the growth stages the reproductive stage recorded the highest N-uptake for all the varieties followed by pod filling stage and vegetative stage respectively. In response to stress at vegetative stage the highest increase in N-uptake of 17.29 kg ha^{-1} (48.44% over control) was recorded in variety Varuna followed by Pusa Agrani with 15.45 kg ha^{-1}. However, in relative terms variety Pusa Agrani recorded the highest increase of 52.4 % over its control. Varieties Pusa Jai Kisan and Pusa Bahar were at par with 11.14 kg ha^{-1} and 11.03 kg ha^{-1} respectively. Similarly, when plants were exposed to water stress at reproductive stage cultivar Varuna again recorded the highest increase in N-uptake with 21.07 kg ha^{-1} followed by Pusa Bahar with a corresponding increase of 19.73 kg ha^{-1} compared to their controls. The respective increases for Pusa Jai Kisan and Pusa Agrani were 17.44 and 17.28 kg ha^{-1} that were at par with each other. However, the highest relative increase of 62.4 % over its control was recorded in variety Pusa Jai Kisan. The N-uptake scenario was similar when plants were left to experience moisture stress at pod filling stage. Varuna also recorded the greatest increase of 18.64 kg ha^{-1} followed by Pusa Agrani with 17.01 kg ha^{-1}. Pusa Bahar and Pusa Jai Kisan were at par with respective increases of 16.14 and 15.95 kg ha^{-1}. Although variety Varuna registered the highest absolute increase of 18.64 kg ha^{-1} in N-uptake but Pusa Agrani registered the highest relative increase of 57.7% over control. Among the varieties under study, the mean N-uptake by Varuna was the highest at 49.94 kg ha^{-1} closely followed by Pusa Bahar with 46.20 kg ha^{-1}. The nitrogen content tended to increase when the plants were subjected to simulated water stress irrespective of varieties and growth stages of the test crop (Table 1, Fig.1)). In general N content increased owing to moisture stress excepting at pod filling stage which exhibited decreasing trend. Among the growth stages, the most of increase were recoded for reproductive stage followed by pod filling and vegetative stage. At pod filling stage, the increase was highest in Pusa Agrani (61.1 % over control) followed by Pusa Jai Kisan (61.7 % over control), Varuna and Pusa Bahar.

3.2 P- Content content and uptakes

From the results it was revealed that P-content increased significantly in all the varieties when the plants were exposed to water stress at different growth stages. P-content significantly increased to a tune of 0.02 % compared to control in varieties Pusa Bahar and Varuna while there was insignificant or no increase in Pusa Jai Kisan and Pusa Agrani varieties. Stress at the reproductive stage was observed to cause an significant increase in the P-content in all the varieties. The greatest increase of 0.06 % was registered both in case of Varuna (14.6% over control) and Pusa Bahr (13.9 % over control) while Pusa Jai Kisan and Pusa Agrani both recorded 0.04 % (11.3 % and 9.7 % respectively compared to their controls). Water stress at pod filling stage also resulted in a significant increase in P-content. The maximum increase of 0.04 % (9.3 % over control) was registered by Pusa Bahar followed by Varuna and Pusa Jai Kisan both with 0.03 % increase and Pusa Agrani the least with 0.02 % compared to respective controls. The highest mean P-content of 0.38 % was recorded by Pusa Bahar and Pusa Agrani recorded the least of 0.35 % P. The study envisaged revealed that P-uptake also increased significantly in all the varieties on being exposed to water stress irrespective of the stages. Stress at reproductive stage was found to have the most pronounced increase in P-uptake irrespective of varieties. Varuna recorded the highest increase (0.32 kg ha^{-1}) in P-uptake in response to water stress at vegetative stage followed by Pusa Bahar with 0.31 kg ha^{-1} which was at par as regards the increase. The increase in P-uptake was insignificant in case of varieties Jai Kisan and Pusa Agrani. When stress was applied at reproductive stage cultivar Varuna recorded the highest increase of 0.68 kg of P ha^{-1} followed by Pusa Bahar with 0.49 kg of P ha^{-1} and Pusa Jai Kisan with 0.22 kg of P ha^{-1}. The increase in P-uptake registered by Pusa Agrani was insignificant. Similarly, stress at pod filling stage also resulted in highest increase of 0.38 kg ha^{-1} in case of Varun followed by Pusa Bahar (0.37 kg ha^{-1}), Pusa Jai Kisan (0.22 kg ha^{-1}) and Pusa Agrani (0.15 kg ha^{-1}). The decrease was significant at pod filling stage irrespective of varieties. Among the varieties, Varuna consistently registered the highest increase in P-uptake at all the three stages followed by Pusa Bahar and Pusa Jai Kisan . While Pusa Agrani exhibited the least decrease of P-uptake in response to stress at any stage of the crop (Table 1, Fig.2). Among the varieties Pusa Bahar recorded the highest mean P-uptake of 5.03 kg ha^{-1}. Phosphorus content increased significantly in the test varieties irrespective of growth stages. Among the growth stages, the increase was most pronounced in case of reproductive stage and least pronounced in vegetative stage. This may be due to lower possessing membrane stability, inherent of the tolerant variety.

3.3 K- Content content and uptakes

K-content significantly increased when plants were exposed to water stress at vegetative stage. The greatest increase of 0.27 % over the control was registered by Pusa Bahar. The corresponding increase for Varuna, Pusa Jai Kisan and Pusa Agrani were 0.23 %, 0.20 % and 0.14 % respectively. Stress at the reproductive stage was found to cause an significant increase in the K-content in all the varieties. The maximum increase of 0.72 % was registered both in case of Pusa Bahar (17.6% over control) and Varuna (17.3% over control). While Pusa Jai Kisan and Pusa Agrani recorded 0.51% (12.8 % of control) and 0.54 % (13.06 % of control) respectively compared to their respective control and were par with each other. Among the stages the increase in K- content was most pronounced in case of reproductive stage and least pronounced in vegetative stage in all the varieties. The highest mean K-content of 3.79 % was recorded by Pusa Agrani. Cultivar Pusa Bahar recorded the highest increase (4.68 kg ha^{-1}) in K-uptake values compared to control when stress was applied at vegetative stage. Varuna was the next high with 3.81 kg ha^{-1}. The other two varieties Pusa Jai Kisan and Pusa Agrani were at par with 2.59 kg ha^{-1} and 2.34 kg ha^{-1} respectively. However, the increase in K-uptake was most pronounced when stress was applied at reproductive stage in all the varieties except Pusa Agrani where the vegetative stress had the maximum impact. The highest increase in K-uptake was recorded for Varuna with 7.89 kg ha^{-1} (17% over control) followed by Pusa Bahar(7.24 kg ha^{-1}), Pusa Jai Kisan(2.92 kg ha^{-1}) and Pusa Agrani(1.91 kg ha^{-1}) respectively when exposed to water stress. Similarly, at pod filling stage the highest increase of 4.01 kg of K-uptake ha^{-1} was registered by Pusa Bahar closely followed by Varun with 3.68 kg ha^{-1}, Pusa Jai Kisan (2.61 kg ha^{-1}) and Pusa Agrani (1.97 kg ha^{-1}) respectively. Among the varieties highest mean K-uptake of 50.17 kg ha^{-1} was registered in case of Varuna followed by Pusa Bahar with 48.59 kg ha^{-1}. Pusa Agrani and Pusa Jai Kisan had the corresponding values of 43.29 and 42.11 kg ha^{-1} (Table 1, Fig.3). When soil water supply is limited, loss of turgor and wilting are typical symptoms of K-deficiency. The lower tolerance of K^+-deficient plants to drought is related mainly to (a) the role of K^+ in stomata regulation, which is a mechanism controlling the water regime of higher plants, and (b) the role K^+ as the predominant osmotic solute in the vacuole, maintaining a high tissue water level even under drought conditions (Marschner, 1995).

Table 1: Effect of water stress and variety on N, P and K content (%) of mustard at Control (S0), Vegetative (S1), Reproductive (S2) and Pod filling (S3) stages.

Variety	Stage of crop growth	N content (%)	P content (%)	K content (%)
Pusa Bahar(V1)	S0	2.55	0.35	3.34
	S1	3.34	0.37	3.61
	S2	4.24	0.41	4.06
	S3	3.81	0.39	3.66
Varuna (V2)	S0	2.65	0.35	3.44
	S1	3.88	0.37	3.67
	S2	4.35	0.41	4.16
	S3	4.10	0.38	3.77
Pusa Jai Kisan(V3)	S0	2.43	0.34	3.49
	S1	3.38	0.34	3.69
	S2	4.22	0.38	4.00
	S3	3.93	0.37	3.82
Pusa Agrani(V4)	S0	2.52	0.34	3.56
	S1	3.77	0.34	3.70
	S2	4.38	0.38	4.10
	S3	4.06	0.36	3.82
Sem ±		0.037	0.004	0.024
CD(0.05)		0.112	0.011	0.067
CV (%)		4.516	4.823	4.643

3.4 Sulphur content content and uptakes

The observations from treatments exposed to water stress during vegetative stage revealed that the S-content decreased significantly in all the varieties. The greatest decrease of 0.47% (35.6% over control) was registered for Pusa Agrani followed by Varuna (0.42%, 30.9% over control), Pusa Jai Kisan (0.39%, 30.7% over control) and Pusa Bahar (0.29%, 24.4% over control). However, stress at reproductive stage resulted a maximum decrease in Varuna (0.71%, 52.2% over control) with the next in Pusa Jai Kisan (0.68%, 53.54% over control). Similarly, moisture stress at pod filling stage resulted in a significant decrease in S-content. The maximum decrease of 0.82% was registered by Varuna (60.3% over control) and Pusa Jai Kian (64.5% over control). While Pusa Agrani and Pusa Bahar recorded 0.77% (58.3% over control) and 0.66 (55.5% over control) respectively compared to their control. The highest mean sulphur content was recorded by Varuna (0.87%) followed by Pusa Agrani (0.85%), Pusa Bahar (0.80%) and Pusa Jai Kisan (0.79%) respectively. Stress at vegetative stage resulted in a decrease of 5.31 kg ha^{-1} in case of Pusa Agrani (27% over control) followed by Varuna (4.69 kg ha^{-1}), Pusa Jai Kisan (4.44 kg ha^{-1}) and Pusa Bahar (3.81 kg ha^{-1}, 24 % over control). Similarly, at reproductive stage a maximum decrease was observed in Varuna (9.05 kg ha^{-1}, 52% over control) followed by Pusa Bahar (8.9 kg ha^{-1}, 55.5% over control). Stress at pod filling stage was found to have the most pronounced decrease in S-uptake irrespective of varieties (Table 2). Varuna recorded the highest decrease (10.35 kg ha^{-1}, 59% over control) in S-uptake and the next Pusa Jai Kisan with 9.56 kg ha^{-1} (65.25 % over control). Among the varieties Varuna recorded the highest mean S-uptake of 11.51 kg ha^{-1}, followed by Pusa Bahar (10.62 kg ha^{-1}), Pusa Agrani (9.79 kg ha^{-1}) and Pusa Jai Kisan (9.08 kg ha^{-1}) respectively.

Table 2: Effect of water stress and variety on S content (%) and S uptake (kg/ha) of mustard at Control (S0), Vegetative (S1), Reproductive (S2) and Pod filling (S3) stages.

Variety	Stage of crop growth	S content (%)	S uptake (kg/ha)
Pusa Bahar (V1)	S0	1.19	16.05
	S1	0.90	12.24
	S2	0.57	7.15
	S3	0.53	7.03
Varuna (V2)	S0	1.36	17.54
	S1	0.94	12.85
	S2	0.65	8.49
	S3	0.54	7.19
Pusa Jai Kisan (V3)	S0	1.27	14.65
	S1	0.88	10.21
	S2	0.59	6.39
	S3	0.45	5.09
Pusa Agrani (V4)	S0	1.32	15.46
	S1	0.85	10.15
	S2	0.68	7.23
	S3	0.55	6.31
Sem ±		0.010	0.159
CD(0.05)		0.027	0.440
CV (%)		8.406	11.365

4. CONCLUSIONS

The nitrogen content of seeds increased significantly when the mustard plants were exposed to water stress. Similarly, the phosphorus and potassium content of mustard seeds were increased. In all the three cases the increase in seed N (64.15 – 73.8%), P (11.76 – 17.15%) and K(14.6 – 21.6%) were more pronounced at reproductive stage. Contrastingly, the S-content of seed decreased significantly in the test cultivars of mustard when the plants were exposed to water stress irrespective of growth stages; the decrease was most significant at pod filling stage (55.46 – 64.6%). The uptake of N, P and K by the seed increased significantly in all the test cultivars on being exposed to water stress. Stress at reproductive stage have the most pronounced effect of increase in uptake of N (17.28 – 21.07%), P (5.63 – 14.59%) and K (4.58 – 17%). The uptakes of the nutrients showed an increasing trend while S-content showed a decreasing trend compared to the respective controls the decrease was most significant at pod filling stage (55.46 – 64.6%). The highest uptake of Nitrogen, Potassium and Sulphur were observed in cultivar Varuna, while P-uptake in Pusa Bahar. The highest decrease of S-uptake was recorded in Varuna (10.39kg ha^{-1}). The inconsistent behaviour of cultivars and effect of growth stages with respect to nutriophysiological responses could not be properly correlated or explained due to lack of supporting evidences.

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Annexure

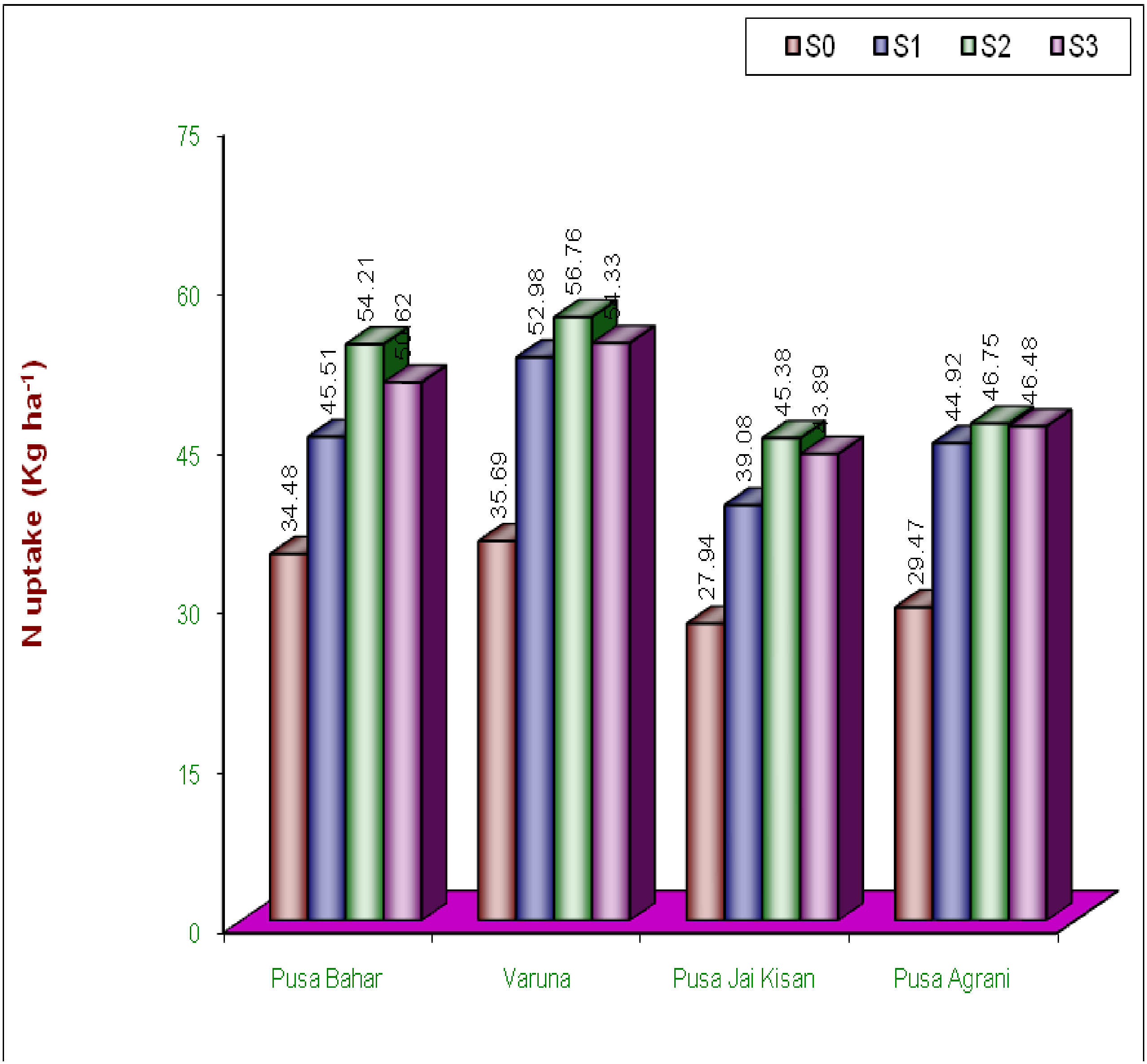

Fig. 1: Effect of water stress and variety on N-uptake (kg ha^{-1}) of mustard of mustard at Control (S0), Vegetative (S1), Reproductive (S2) and Pod filling (S3) stages.

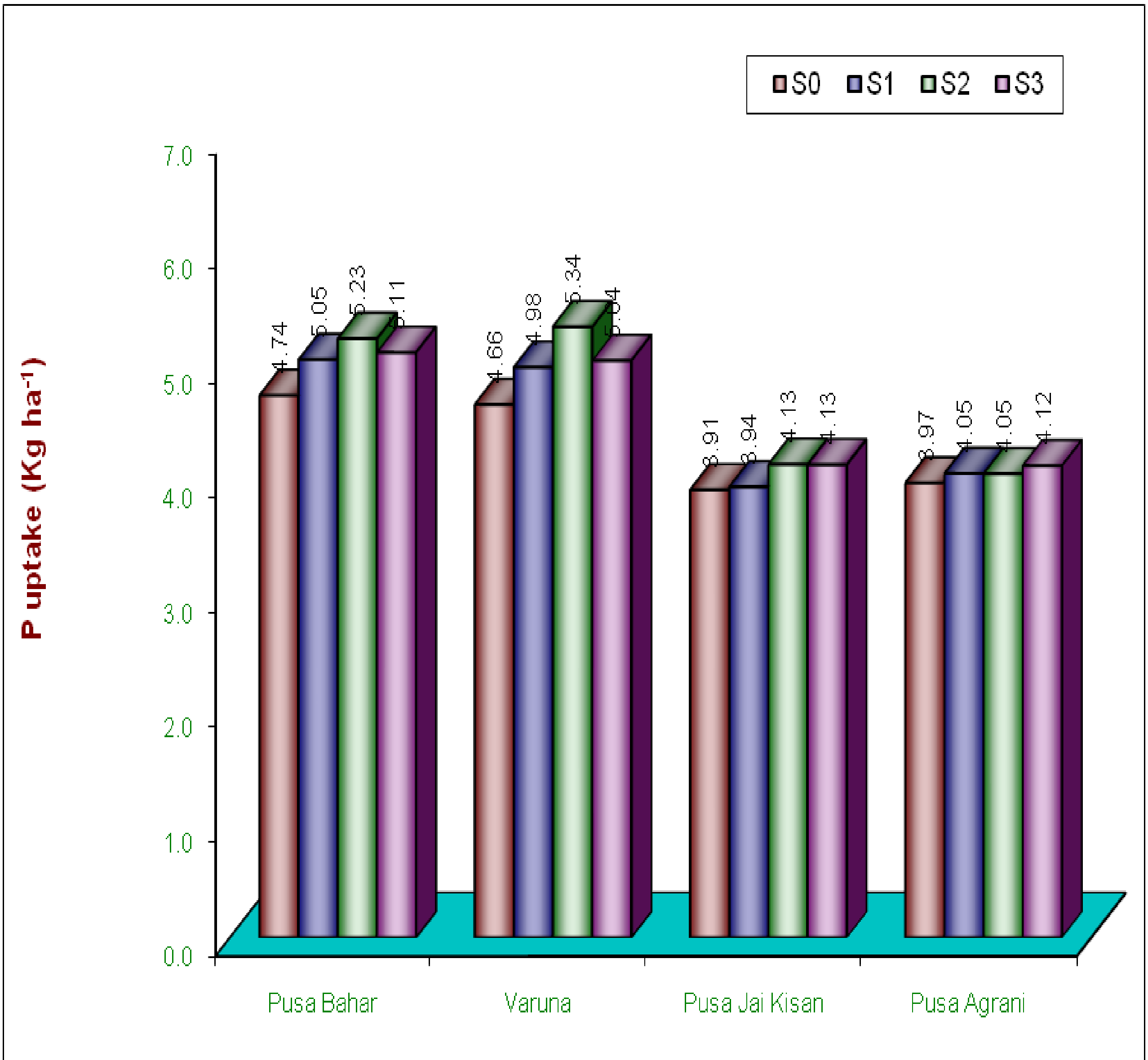

Fig. 2: Effect of water stress and variety on P-uptake (kg ha^{-1}) of mustard of mustard at Control (S0), Vegetative (S1), Reproductive (S2) and Pod filling (S3) stages.

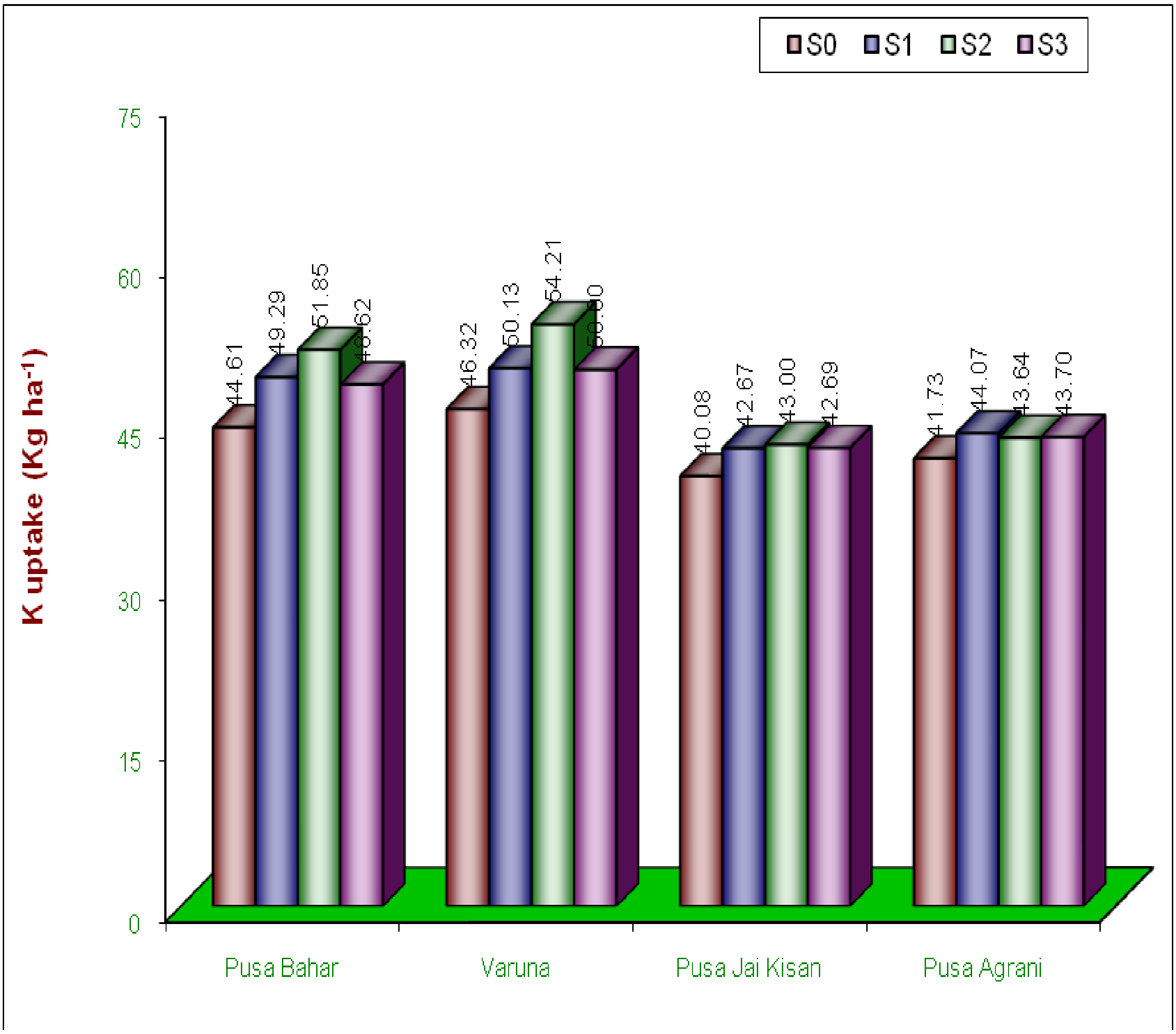

Fig. 3: Effect of water stress and variety on K-uptake (kg ha^{-1}) of mustard of mustard at Control (S0), Vegetative (S1), Reproductive (S2) and Pod filling (S3) stages.