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EFFECT OF COMBINED VARIATION IN LIGHT IRRADIANCE AND POTASSIUM ON RICE (*ORYZA SATIVA* L.)

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Abstract

The influence of varied potassium nutrition (20 and 40 ppm) at two levels of light irradiance on rice (*Oryza sativa* L.) indicated that low light irradiance operative from 40 days after planting (DAP) to harvest reduced all physiological parameters studied, at flowering and harvest stage though leaf area, specific leaf weight (SLW), chlorophyll and sterility increased at both potassium levels. During the transition from vegetative to the reproductive phase the 40 ppm potassium supply could partially compensate, the photosynthetic rate (Pn), stomatal conductance (C_s), soluble protein and chlorophyll. At harvest, however, the positive effect of K became weaker and there was no increase in dry matter and yield but under normal light irradiance elevated K increased the total dry matter and yield. Thus, potassium raised the photosynthetic rate and vegetative growth under low irradiance but this was not capable of promoting the filling of grains in inadequate illumination.

Key words : Light irradiance, potassium, rice.

Potassium is often believed to play an important role in flowering process as it is one of the essential macronutrients. The role of potassium in opening of stomatal aperture has been shown in several crop species, thus, allowing carbon dioxide to enter into the cells for photosynthetic process. Conversely, low light irradiance promotes the closure of stomata. Our earlier findings (Singh *et al.*, 1988, Day *et al.*, 1989, Voleti *et al.*, 1991) indicate that light irradiance is yield limiting factor in rice. It has been observed that a high level of potassium nutrition can reduce the decline in yield due to inadequate illumination. There are, however, certain contradictory reports to this effect (Haeder and Mengel, 1976). Further, the effects of low light are often carried forward to the grain filling stage through various metabolic processess. Stomatal aperture control by potassium, consequently increases in the availability of CO_2 substrate for photosynthesis and this might influence the yield. The objective of the present study is to find out whether potassium nutrition has any influence on yield of rice under low irradiance.

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Materials and Methods

Twenty-day old seedlings of rice cv. Ratna were transplanted in porcelain pots, containing eight kg air dry soil. Four hills per pot were maintained throughout the experimental period with recommended doses of nitrogen and phosphorus. Potassium at 20 ppm and 40 ppm (K_1 and K_2) was applied 10 days after planting (DAP) and at primordial initiation stage (PI). Half of the pots were transferred to low light irradiance (50% of normal light) as described earlier (Singh *et al.* 1988). Crop growth rate (CGR) and net assimilation rate (NAR) were recorded during 40 DAP and flowering stages. Photosynthesis rate (Pn), stomatal conductance (Cs), soluble protein and chlorophyll were measured in the flag leaf on main tiller at flowering stage, using LICOR-6000 Portable Photosynthesis System (Nebraska, USA), Lowry *et al.* (1951) and Arnon (1949), respectively. Yield and yield components were recorded at harvest with five replications. Shade tolerance index (SI) expressing positive or negetive effect of low light irradiance on a particular parameter was calculated as described earlier (Singh *et al.*, 1988). The data is analysed statistically for the treatments and their interaction effects using a computerised programme.

Results and Discussion

Results on various physiological parameters are presented in Table 1. Tiller number was reduced by 19% in K_1 and 28% in K_2 under low light irradiance but marginal increase occured by K_2 treatment under normal light. Leaf area was increased by 3 and 5% in K_1 and K_2, respectively, in low light. Both potassium levels as such were also able to increase leaf area irrespective of light. Leaf area increase was perhaps at the expanse of specific leaf weight (SLW or leaf thickness) as it was reduced by 30% and 20% under low irradiance in K_1 and K_2, respectively. Leaves under K_2 were thinner even in normal light irradiance. However, K_2 was able to check further reduction in the thickness of leaves under low irradiance as is indicated by higher shade index for K_2 (Table 2). Crop growth rate (CGR) was drastically reduced by 66% under low irradiance in both K levels. However, high potassium level improved it marginally irrespective of light conditions though the differences were non-significant. Net assimulation rate (NAR) was also drastically reduced under low irradiance and higher potassium level further aggravated the situation. Total dry matter (TDM) at flowering stage also declined steeply under low irradiance, however, K_2 ameliorated it marginally as indicated by high shade index for K_2 (Table 2). Higher potassium level also improved TDM significantly, irrespective of light condition.

Photosynthetic rate at flowering stage in flag leaf was reduced more in K_1 than in K_2 under low irradiance, K_2 was able to increase photosynthetic rate irrespective of prevailing light condition. Stomatal conductance (Cs) also behaved in similar fashion as photosynthetic rate. Similarly, soluble protein which is considered to give a rough estimate of RuBPCase also behaved in tandem with photosynthetic rate

Table 1. Effect of combined variation in light irradiance and potassium nutrition on physiological parameters in rice

Parameter	Potassium (K_1) (20 ppm) Normal light	50% light	% increase or decrease	Potassium (K_2) (40 ppm) Normal light	50% light	% increase or decrease	C.D. at 5% K	L	K x L
Tiller No. pot^{-1}	32.00	26.00	-19	36.00	26.00	-28	1.87	1.87	2.64
Leaf area dm^{-2} pot^{-1}	27.90	28.90	+3	30.90	32.50	+5	0.817	0.817	NS
Specific leaf wt. mg dm^{-2}	434.00	304.00	-30	423.00	338.00	-20	3.82	3.82	5.41
CGR g pot^{-1} d^{-1} (40 DAP-flowering)	1.49	0.50	-66	1.53	0.52	-66	0.037	NS	NS
NAR mg dm^{-2} d^{-1} (40 DAP-flowering)	71.00	23.00	-68	65.00	21.00	-68	1.81	1.81	2.55
TDM g pot^{-1} (flowering)	41.80	21.90	-48	45.80	24.90	-46	0.79	0.79	NS
Photosynthetic rate mg CO_2 dm^{-2} hr^{-1}	36.50	22.60	-38	38.60	24.70	-36	0.65	0.65	NS
Stomatal conductance cm s^{-1}	1.79	1.35	-25	1.85	1.43	-23	0.040	0.040	NS
Soluble protein mg dm^{-2}	30.40	22.80	-25	31.60	23.00	-27	0.76	NS	NS
Chlorophyll a mg g^{-1} fresh wt.	3.25	3.84	+18	3.30	3.92	+19	0.031	0.031	NS
Chlorophyll b mg g^{-1} fresh wt.	1.16	1.46	+26	1.18	1.51	+28	0.043	NS	NS
Chlorophyll a/b ratio	2.80	2.63	-6	2.80	2.60	-7	0.086	NS	NS

Table 2. Shade tolerance index for various physiological variables as affected by potassium levels

Variables	20 ppm potassium	40 ppm potassium
Tiller number	81	72
Leaf area	103	105
Specific leaf weight	70	80
Crop growth rate	34	34
Net assimilation rate	32	32
Total dry matter	52	54
Photosynthetic rate	62	64
Stomatal conductance	75	77
Soluble protein	75	73
Chlorophyll 'a'	118	119
Chlorophyll 'b'	126	128
Chlorophyll a/b ratio	94	93

and stomatal conductance. Rate of increase in the chlorophyll b was higher than total and chlorophyll a, under low irradiance. Both chlorophyll a and b increased in K_2, irrespective of light conditions. Elucidating the same trend, chlorophyll a/b ratio was reduced by 6 and 7% under low irradiance in K_1 and K_2, respectively.

Results obtained on yield and yield components are shown in Table 3. TDM at harvest was drastically reduced under low irradiance by 55 and 58% in K_1 and K_2, respectively. K_2 was able to improve TDM in normal irradiance, but reduction was more in low irradiance (Table 4). Panicle number also declined more in K_2 under low

RuBPCase, may be substrate inducible as more CO_2-substrate is available at elevated potassium level. Thus vegetative growth is further augmented by better utilization of absorbed solar energy for photosynthesis and phloem loading (Haeder and Mengel, 1975). Potassium also increases the velocity of the streaming movement of the assimilated substances in the sieve tube (Haeder, 1974), and these substances are converted (by means of K-activated enzymes) at enhanced rates into starch/protein within the tissue that receive them (Evans and Wildes, 1971, Hawker *et al.*, 1974). Elevated potassium supply keeps roots healthy for longer time to synthesize cytokinin-which prolong leaf area duration of leaves to stay back green (Wagner and Michael, 1971) thus, influencing photosynthesis. Reduction in NAR and SLW at elevated potassium may be due to the increase in leaf area at the expense of NAR and SLW.

Fifty per cent light intensity induced a marked fall in tiller number, TDM, CGR, NAR, photosynthetic rate, stomatal conductance, soluble protein and chlorophyll a/b ratio, while there was marginal increase in leaf area, chlorophyll a and b and total chlorophyll at both K levels (Table 2). These findings corroborate our earlier findings (Singh *et al.*, 1988, Day *et al.*, 1989). During flowering stage it seems that higher K supply compensated for light deficiency to some extent as reflected in few caracters viz. Pn, SLW, Leaf area, chlorophyll and TDM. Fifty per cent light at harvest, resulted in reduction in TDM, yield and yield components at both K levels and increased the grain sterility (Table 4). Thus, the positive effects of potassium become further weaker so that TDM was almost equal, yield or grain weight was low while sterility was higher. The decrease in yield under elevated potassium supply is mainly derived from reduction in panicle number, grain number and 1000-grain weight. further, from spikelet number it is clear that higher potassium supply could not increase the sink capacity especially under low light irradiance.

Potassium although raised the photosynthetic rate and vegetative growth under low light irradiance (Table 1). However, this was not capable of promoting the filling of the grains (higher sterility in K_2 Table 3). suffered higher respiration losses due to congestion of assimilated substrates (Haeder and Mengel, 1976). Grain filling is dependent not only on the production of photoassimilates and their translocation but is also conditioned by sink capacity of developing grain itself. In shaded plants potassium did not fundamentally affect sink capacity of the grain. Thus, yield components, under low light irradiance, reduced than improved by an elevated potassium supply.

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Table 3. Effect of combined variation in light irradiance and potassium nutrition on yield and yield components in rice

Parameter	Potassium (K_1) (20 ppm)			Potassium (K_2) (40 ppm)			C.D. at 5%		
	Normal light	50% light	% Increase of decrease	Normal light	50% light	% increase of decrease	K	L	K x L
TDM at harvest g pot^{-1}	55.5	24.9	-55	60.2	25.0	-58	1.07	1.07	1.51
Panicle No. pot^{-1}	22.0	20.0	-9	23.0	19.0	-17	1.54	NS	NS
Grain weight g pot^{-1}	17.4	7.0	-60	19.0	6.4	-66	0.57	NS	0.82
Spikelet No. pot^{-1}	1374.0	866.0	-37	1384.0	855.0	-38	7.52	NS	10.64
Grain No. pot^{-1}	921.0	407.0	-56	955.0	376.0	-61	7.32	NS	10.35
Sterility (%)	33.0	53.0	+61	31.0	56.0	+81	1.94	NS	NS
1000-grain weight	18.9	17.2	-9	19.9	17.0	-15	0.40	0.40	0.56

Table 4. Shade tolerance index for yield and yield components in rice as affected by potassium levels

Variables	20 ppm potassium	40 ppm potassium
Total dry matter	45	42
Panicle number	91	83
Grain weight	40	34
Spikelet number	63	62
Grain number	44	39
Sterility %	161	181
Test weight	91	85

irradiance. Total grain weight was drastically reduced in low light and more pronounced under higher potassium level. The number of spikelets were significantly affected by light conditions but not by potassium levels. Similarly, grain number also declined under low irradiance and more so under K_2. Sterility was increased by 61% in K_1 and 81% in K_2 under low light irradiance. Higher potassium as such has no impact on sterility even under low light irradiance. Thousand grain weight was reduced under low light irradiance under both K levels, more so at higher potassium level.

Under normal light condition plants with the elevated potassium supply performed invariably better than with lower level of potassium almost for all the parameters studied at flowering stage. However, specific leaf weight and NAR showed declining trend. Increase in TDM and photosynthesis is in confirmity with the results of Mengel and Haeder (1975) and Haeder and Mengel (1976) in wheat. The role of potassium in increasing yields is due to its various effects during the whole life cycle of growth. Vegetative growth is stimulated by potassium as is reflected in TDM. Cooper *et al.* (1987) has attributed the K induced increase in photosynthetic rate to a greater number of stomata per unit leaf area, and larger stomatal aperture in the greater mass of leaf, which are accompained by lowering of CO_2 compensation point. Therefore, the effectiveness in CO_2 assimilation is more (Tanaka and Hara, 1974). Increase in soluble protein - major portion of which is

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