2 *Egypt. J. Agron.* **Vol. 33**, No. 1, pp. 19-33 (2011)

Response of Hybrid Rice to Time and Method of Potassium Application

T.F. Metwally and H.S. Gharib*
*Rice Res. and Training Center, Field Crops Res. Inst., Agric. Res. Center, Sakha – Kafrelshiekh and *gronomy Dept., Fac. Agric., Kafrelshiekh University, Kafrelshiekh, Egypt.*

TWO FIELD experiments were carried out at the experimental farm of the Rice Research and Training Center, Sakha, Kafrelshiekh, Egypt, during 2009 and 2010 seasons, to study the response of hybrid rice (Egyptian Hybrid1) to methods (soil addition and foliar spray (S)) and time of potassium application. Eleven combinations were studied as follow applications times: (T_1) without k fertilizer , (T_2) 24+0+0, (T_3) 8+8+8, (T_4) 8+8+S, (T_5) 12+12+S, (T_6) 8+ S +S, (T_7) 12+ S +S, (T_8) 24+ S +S, (T_9) 0+ S +0, (T_{10}) 0+ 0 +S and (T_{11}) 0+ S +S kg K_2O/fed. (feddan = 0.42 hectare) at basal (B), med tillering (MT) and panicle initiation (PI) stages, respectively, as well as (11) without K fertilizer.

The results revealed that basal application of K or foliar spray twice each at MT and PI stages resulted in a significant increase in plant height and dry matter accumulation ($g.m^{-2}$) compared with control in both seasons. Soil or foliar application of K, separately or together, resulted in a significant increase in number of panicles m^{-2}, panicle weight, panicle length, number of filled grains per panicle, 1000-grain weight, grain yield and nutrients uptake (N, P, K and Zn) in grains compared with control treatment in both seasons.

Split application of 24 kg K2O/fed in three equal doses was found to better grain yield, yield attributes and nutrients uptake in grains than entire basal application or foliar spray at MT or PI stages alone.

The integration of basal application and either top dressing or foliar K in MT and PI stages did not differ from splitting K in three equal doses in the most mentioned traits in both seasons. However, basal application of 24 kg K_2O/fed alone or along with foliar spray at MT and PI produced the highest straw yield and nutrients uptake (N, P, K and Zn) in straw in the two seasons. There was no significant difference in straw yield among foliar application of potassium and control treatment. The treatment containing soil application of K twice at basal and MT stage, or entire basal application alone were insignificantly with entire basal along with foliar application of K at MT and PI stages in N, P, K and Zn uptake in straw in both seasons. The correlation among each of nutrient content and grain and straw yields were significantly positive.

The present study concludes that splitting 24 kg K_2O/fed in three equal doses, *i.e.* 8+8+8 or the combination of top dressing (kg K_2O/fed) and foliar spray (S), 8+8+S, 12+S+S and 8+S+S at basal, MT and PI stages are a viable nutrient management package for getting higher grain yield of hybrid rice (Egyptian Hybrid1) at Kafrelshiekh Governorate.

Potassium deficiencies in upland, as well as lowland, occur in rice less frequently than N and P deficiencies. However, with the intensive use of soil and of high-yielding cultivars, soil reserves of K will not be sufficient to maintain productivity for a long time. Under these circumstances, use of K-efficient cultivars can be a complementary solution to overcome K deficiency (Fageria *et al*., 1997).

Recently attention has been given to K nutrition, with hybrid rice behaving physiological advantage in nutrient uptake and use efficiency than inbred rice to achieve higher yield potential (Liu & Liu, 1997 and Hu & Wang, 2003, 2004). Hybrid rice has a yield advantage of 15–20% over inbred cultivars (Tu *et al.*, 2000 and Yuan, 2004). Hybrid rice cultivars take up more K due to a well-developed root system and vigorous growth than do the ordinary rice varieties (Xu & Bao, 1995).

Potassium is a macronutrient involved in many plant processes critical for optimum growth, yield and quality of crops. K plays a number of indispensable roles in a wide range of functions: photosynthesis, enzyme activation, protein synthesis, osmotic potential and as a counter ion to inorganic ions and organic biopolymers. Potassium is involved in sugar translocation and is an important counter-anion for NO_3 transport in the xylem. The transport rate of solutes in the phloem depends on the plant K concentration (Marschner, 1995). K fertilization had a significant effect on the nutrient content in straw and grain as N, P, K and Zn (Brohi *et al.,* 2000).

Split application of potassium fertilizer in rice may give higher nutrient use efficiency than its single application (Tandon &Sekhon, 1988). Surendran (2005) indicated that two equal split application of potassium, at tillering and panicle initiation stages increased the growth and yield attributes of rice and N, P and K uptake compared to basal application. Awan *et al.* (2007) concluded that potash application in two splits, ½ as basal and ½ at 25 days after transplanting, resulted in more number of grains per panicle, highest 1000 grain weight and maximum paddy yield. Samrathlal *et al.* (2003) claimed that grain and straw yields of rice crop were increased significantly owing to potash fertilization when applied in two equal splits. The highest paddy yield and its attributes were obtained in treatment receiving split use of potash as ½ at 25 and ½ at 45 days after transplanting and the lowest yield related attributes were achieved when all potash was applied as basal (Manzoor *et al*., 2008). Gorgy *et al.*(2009) found that split-applied potassium with three doses (50% at basal + 25% at mid tillering + 25% at panicle initiation) gave the highest values of dry matter, N and K shoot content, panicle number, filled grains%, panicle weight, 1000-grain weight, harvest index (HI) and grain yield of Egyptian hybrid rice.

Foliar application of K_2O results in fast K absorption and has the advantage of quickly correcting deficiencies. Other advantages are low application rates, and uniform distribution of fertilizer. However, foliar fertilization is supplementary to and cannot replace the basal fertilization (Kafkafi *et al*., 2001). In rice, a foliar application of potassium at panicle initiation, booting and 50% flowering stages significantly increased grain yield (Jayaraj & Chandrasekharan, 1997). Splitting potassium fertilizer to rice, a third at sowing in soil, a third as a foliar at flag leaf stage and a third at grain development, gave larger yields than a soil application all at sowing (Narang *et al.*, 1997).

Therefore, the present investigation was planned to find out the best suited time and method of potassium fertilizer application for hybrid rice (Egyptian Hybrid1).

Materials and Methods

Two field experiments were carried out on clay soil at the experimental farm of the Rice Research and Training Center (RRTC), Sakha, Kafrelshiekh, Egypt, during 2009 and 2010 rice seasons, to study the response of hybrid rice (Egyptian Hybrid1) to split and foliar application of potassium fertilizer. The previous crop was barley in the two seasons. Representative soil samples were taken from each site at the depth of 0-30 cm from the soil surface. Samples were air-dried, then ground to pass through a two mm sieve and well mixed. The procedure of soil analysis followed the methods of Black *et al.* (1965). Results of chemical analysis in both seasons are shown in Table 1. Potassium fertilizer in the form of potassium sulphate (50% K_2O) was applied with two methods (soil and foliar applications) at three times (basal "B", med tillering stage "MT" and panicle initiation stage "PI"). Med tillering and panicle initiation stage of Egyptian Hybrid1 were at 48 and 65 days after sowing. Soil application of potassium at the recommended rate 24 kg K_2O/fed (feddan = 0.42 hectare), was split in three or two doses. Foliar spray of K was applied with solution of 2 % K_2O. Eleven combinations among soil, foliar application and time of potassium application were applied, according to the data given in Table 2.

TABLE 1. Chemical analysis of the experimental soil (0-30 cm depth) in 2009 and 2010

seasons.

Characters	2009	2008
pH (1 : 2.5)	8.1	8.0
EC (dS.m^{-1})	2.3	1.9
Organic matter (%)	1.5	1.7
Available N (ppm)	18.6	19.5
Available K (ppm)	323	358
Available P (ppm)	16.5	17.2
Available Zn (ppm)	0.93	0.65
Available Fe (ppm)	3.12	3.64
Available Mn (ppm)	3.6	2.93

TABLE 2. Scheme of potash application.

Soil application (kg K_2O/fed) and foliar spray (S)				Total (kg K_2O/fed + S No.)
Term	**Basal**	**MT**	**PI**	
T_1	-	-	-	Without K (control)
T_2	24	-	-	24
T_3	8	8	8	24
T_4	8	8	S	16 + 1 S
T_5	12	12	S	24 + 1 S
T_6	8	S	S	8 + 2 S
T_7	12	S	S	12 + 2 S
T_8	24	S	S	24 + 2 S
T_9	-	S	-	1 S
T_{10}	-	-	S	1 S
T_{11}	-	S	S	2 S

B = basal, MT= med tillering stage, PI = panicle initiation stage, S = foliar spraying with 2% K_2O.

The experimental design was randomized complete block design (RCBD) with four replications. The plot size was 3 m x 4 m (12 m^2). Plots were isolated by levees 1.5 m wide. The experimental soil was fertilized with phosphorus in form of calcium superphosphate (15.5 % P_2O_5) at the rate of 21 kg P_2O_5/fed before the soil preparation. Nitrogen fertilizer at the rate of 70 kg N/fed in the form of urea (46.5% N) was added in three equal splits at basal before transplanting, at mid tillering and panicle initiation.

Seeds, at a rate of 10 kg/fed were soaked in water for 24 hr then incubated for

48hr to hasten early germination. Pre-germinated seeds were uniformly broadcasted in the nursery on 1st May and 25th April of the two seasons, respectively. The permanent field was well prepared, *i.e.* plowed twice followed by good wet leveling. Seedlings were carefully pulled from the nursery after 30 days from sowing and distributed through the plots. Seedlings were manually transplanted in 20X20 cm spacing at the rate of 2-3 seedlings/hill. Seven days after transplanting the herbicide Saturn 50% [S-(4-Chlorophenol methyl) diethyl carbamothioate] at the rate of 2 L/fed was mixed with enough sand to make it easy for homogenous distribution. Plots were kept flooded till 2-3 weeks before harvesting. All other agronomic practices were followed as recommended for the location during the growing season.

Plant samples (five hills each) were taken randomly from each plot at heading to estimate the plant height (cm) and dry matter (g. m^{-2}). At harvesting, number of panicles per m^2 was counted. Ten panicles were collected randomly to estimate the panicle weight (g), panicle length (cm), number of filled grain and unfilled grain per panicle and 1000-grain weight. The total weight of both grain and straw was recorded as tons per feddan. The weight of grains was adjusted to 14% moisture content. Samples were taken from grain and straw at harvest to determine N, P, K and Zn contents. All samples were oven dried to a constant weight at 70^{o}C, then ground to powder and digested, according the method of Chapman & Pratt (1961). Total N was determined by Micro Kjeldahl method (Black,1965), K by the flam photometer by using Atomic Absorption method of Yoshida *et al.* (1972), P calorimetrically by ascorbic acid according to Watanabe & Olsen (1965) and Zn by using Atomic Absorption method as described by Jackson (1967). N, P and K (kg/fed) and Zn uptake (g/fed) in grain and straw were calculated.

The obtained data were subjected to analysis of variance according to Gomez & Gomez (1984). Treatment means were compared by Duncan's Multiple Range Test (Duncan, 1955). Coefficients of correlation among nutrients content and grain yield, as well as straw yield, were computed according to Gomez & Gomez (1984). All statistical analyses were performed using analysis of variance technique by means of "MSTATC" computer software package.

Results and Discussion

Growth

Means of plant height and dry matter accumulation by rice plant of E.Hybrid1 at heading as affected by split application of potassium in 2009 and 2010 are presented in Table 3. Split application of potassium had a significant effect on plant height and dry matter accumulation (g. m^{-1}) of E. Hybrid1 in both seasons. Basal application of potassium or foliar spray with 2% K_2O solution at med tillering (MT) and panicle initiation (PI) stages resulted in a significant increase in plant height and dry matter accumulation (g. m^{-1}) compared with control in both seasons. Data show that basal application of 24 kg K_2O/fed alone or along with foliar 2% K_2O at MT and PI stages was superior to foliar 2% K_2O alone in plant height and dry matter accumulation (g. m^{-1}) in the two seasons. Treatments involving top dressing of K twice (each at basal and med tillering stages) or 12 kg K_2O as basal along with foliar 2% K_2O at MT and PI stages were insignificantly with application of 24 kg K_2O/fed as basal in these growth traits.

TABLE 3. Plant height and dry matter accumulation of Egyptian Hybrid1 at heading as affected by split application of potassium in 2009 and 2010.

Treatment (kg k_2O/fed)				Plant height (cm)		Dry weight (g. m^{-2})	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	88 f	98 d	948 e	1040 e
T_2	24	-	-	107 a	115 a	1469 a	1474 ab
T_3	8	8	8	103 abc	110 abc	1369 ab	1350 abc
T_4	8	8	S	102 a-d	108 abc	1335 abc	1327 abc
T_5	12	12	S	106 ab	112 ab	1414 ab	1470 ab
T_6	8	S	S	100 b-e	107 abc	1297 bc	1304 bc
T_7	12	S	S	104 abc	110 abc	1386 ab	1409 ab
T_8	24	S	S	108 a	115 a	1496 a	1496 a
T_9	-	S	-	96 de	105 bcd	1134 d	1118 de
T_{10}	-	-	S	95 e	103 cd	1091 de	1089 de
T_{11}	-	S	S	98 cde	106 bc	1190 cd	1215 cd

B = basal MT = med tillering stage PI = panicle initiation stage S = foliar spraying with 2% K_2O.
In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

The increase in plant height and dry matter accumulation due to foliar K at MT and PI stages indicate that under transplanted conditions of hybrid rice, requirement of K at early stages are met by the indigenously available soil K and then the requirement of K at tillering and panicle initiation stage was best satisfied by the application of K (top dressing or foliar spraying) receiving at respective stages.

Application of K in proper time (split doses) enhanced the enzymatic activities, probably caused higher mobilization of nutrients in soil and plant and translocation of photosynthetic in plant system, which ultimately resulted in higher dry matter accumulation. Our results are in agreement with the findings of Surendran (2005), Hashem (2010) and Mikhaael (2010) .

Yield attributes

There were substantial differences among splitting K treatments in all measured yield attributes in both seasons (Tables 4 and 5). Soil or foliar application of K separately or together resulted in a significant increase in the number of productive tillers (number of panicles m^{-2}), panicle weight, panicle length, number of filled grains per panicle and 1000-grain weight, compared with control treatment (without K application) in both seasons. Application of 24kg K_2O/fed in three equal splits at basal, MT and PI stages recorded a higher yield attributes than entire basal application of K alone or foliar K at MT or PI stages without basal K in both seasons. The addition of basal application and either top dressing or foliar K in MT and PI stages did not differ from splitting K in three equal splits in most yield attributes in both seasons. The addition between soil and foliar application of K at basal and med tillering and panicle initiation stages was found to be the better method of K application and reflected by more number of productive tillers, filled grains per panicle, higher 1000-grain weight, panicle length, and lesser unfilled grains. Fractional application of K at basal and active growth stages (MT and PI) resulted in adequate potash supply which may be increased plant photosynthesis rate because potash is required in the activation of starch synthesis and then conversion of soluble sugars into starch in a vital step during the grain filling process. Positive responses of K application on yield attributes have also been reported by Surendran (2005), Gobi *et al.* (2006) and Gorgy *et al.* (2009).

TABLE 4. Number of panicles m^{-2}, panicle weight and panicle length of Egyptian Hybrid1 as affected by split application of potassium in 2009 and 2010 seasons.

kg k_2O/fed.				Panicles (m^{-2})		Panicle weight (g)		Panicle length (cm)	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	479 d	485 e	3.88 d	3.81 d	22.3 c	22.7 d
T_2	24	-	-	517 c	535 cd	4.46 c	4.39 c	23.5 b	23.8 c
T_3	8	8	8	593 a	612 a	5.19 a	5.13 a	25.3 a	25.4 a
T_4	8	8	S	579 a	601 ab	5.06 ab	4.99 ab	25 a	25.2 ab
T_5	12	12	S	586 a	604 ab	5.17 a	5.1 a	25.3 a	25.3 ab
T_6	8	S	S	557 abc	571 a-d	4.64 bc	4.55abc	24.8 a	24.5abc
T_7	12	S	S	565 ab	579 abc	4.98 ab	4.56abc	24.8 a	24.7abc
T_8	24	S	S	576 a	595 ab	4.85abc	4.71abc	24.8 a	24.8abc
T_9	-	S	-	532 bc	558 bcd	4.63 bc	4.47 bc	24.7 a	24.4abc
T_{10}	-	-	S	525 bc	529 d	4.46 c	4.34 c	23.5 b	24.0 c
T_{11}	-	S	S	535 bc	569 a-d	4.49 c	4.49 bc	24.5 ab	24.3 bc

B = basal, MT = med tillering stage, PI = panicle initiation stage, S = foliar spraying with 2% K_2O.
In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

TABLE 5. Number of filled and unfilled grains per panicle and 1000-grain weight of

Egyptian Hybrid1 as affected by split application of potassium in 2009 and 2010 seasons.

kg k_2O/fed				Filled grains per panicle		Unfilled grains per panicle		1000-grain weight (g)	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	142 c	150 d	9.7 a	9.9 a	24.24 d	24.01 d
T_2	24	-	-	167 b	168 c	7.2 bc	8.1 b	24.73 c	24.51 c
T_3	8	8	8	199 a	197 a	5.3 c	4.8 d	25.4 a	25.21 a
T_4	8	8	S	191 ab	195 ab	5.4 c	5.1 cd	25.14abc	25.02 ab
T_5	12	12	S	198 a	195 ab	5.4 c	5.5 cd	25.26 ab	25.17 a
T_6	8	S	S	177 ab	178 bc	6.2 bc	6.5 bcd	25.03abc	24.83abc
T_7	12	S	S	183 ab	180 abc	6 bc	6.5 bcd	25.16abc	25.09 ab
T_8	24	S	S	186 ab	179 abc	5.4 c	6.3 bcd	25.1 abc	24.93abc
T_9	-	S	-	169 b	178 bc	6.3 bc	6.7 bc	25.01abc	24.78abc
T_{10}	-	-	S	165 b	169 c	7.3 b	8 b	24.86 bc	24.7 bc
T_{11}	-	S	S	171 b	174 c	7.1 bc	7.8 b	24.98abc	24.73 bc

B = basal MT = med tillering stage PI = panicle initiation stage S = foliar spraying with 2% K_2O.
In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

Grain and straw yields

Means of grain yield, straw yield and harvest index of E. Hybrid1 as affected by split application of potassium in 2009 and 2010 are presented in Table 6. Grain and straw yields were substantially influenced by time and method of K application in both seasons. Rice plants that received potassium through top dressing or foliar application out yielded control plants in grain yield in the two seasons. Maximum grain yield was recorded by the application of K in three equal splits at basal, MT and PI stages, which was statistically higher than the entire basal application or foliar spray of K separately in both seasons.

All combinations of K application as top dressing and foliar spraying at basal, MT and PI stages were insignificantly with application of K in three equal splits in grain yield in both seasons. The increase in grain yield due to splitting K as mentioned before was attributed directly to continuous supply of K during different crop growth stages. A significant increase in number of panicles per m^2, panicle length, number of filled grain per panicle and 1000-grain weight ultimately resulted in maximum grain yield. These results are in accordance with those reported by Ali *et al.* (2005), Surendran (2005), Awan *et al.* (2007), Manzoor *et al.* (2008), Gorgy *et al.* (2009), Kavitha *et al.* (2009) and Hashem (2010), who reported that significant increase in baddy yield was recorded when potash was applied in splits at different growth stages over single application as basal. Manjappa *et al.* (2008) found a significant response by rice for grain yield due to foliar application of potassium compared to no foliar application.

TABLE 6. Grain yield, straw yield and harvest index of Egyptian Hybrid1 as affected by split application of potassium in 2009 and 2010 seasons.

kg K_2O/fed.				Grains yield (ton/fed)		Straw yield (ton/fed.)		Harvest index	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	5.16 e	5.07 c	5.76 c	5.78 c	0.486	0.480
T_2	24	-	-	5.49 d	5.44 b	6.45 ab	6.87 a	0.461	0.442
T_3	8	8	8	6.04 a	6.49 a	6.29 abc	6.47 ab	0.496	0.504
T_4	8	8	S	5.90 abc	6.38 a	6.17 abc	6.44 ab	0.495	0.502
T_5	12	12	S	5.99 ab	6.46 a	6.36 ab	6.79 a	0.491	0.491
T_6	8	S	S	5.70 a-d	6.12 a	6.00 bc	6.41 ab	0.486	0.490
T_7	12	S	S	5.75 a-d	6.24 a	6.35 ab	6.60 ab	0.474	0.490
T_8	24	S	S	5.79 a-d	6.29 a	6.65 a	6.96 a	0.471	0.479
T_9	-	S	-	5.64 bcd	5.63 b	5.99 bc	6.18 bc	0.485	0.468
T_{10}	-	-	S	5.57 cd	5.45 b	5.94 bc	6.09 bc	0.484	0.473
T_{11}	-	S	S	5.59 cd	5.48 b	6.06 bc	6.32 bc	0.480	0.461

B= basal, MT= med tillering stage, PI = panicle initiation stage, S= foliar spraying with 2% K_2O. In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

Data in Table 6 show that straw yield was significantly increased by treatments involving 12 or 24 kg K_2O/fed as basal, compared with control (no k application) in both seasons. There was no significant difference among foliar application of potassium and control treatments in both seasons. Single basal application of 24 kg K_2O/fed or along with foliar at MT and PI produced the highest straw yield in the two seasons. The trend of results is similar to those of dry matter accumulation and similar discussion could be cited. Manjappa *et al.* (2008) also reported that the influence of foliar spray on straw yield was not significant. They added that the interaction effect of soil and foliar applied K was significant in one season, only. Surendran (2005) found that application of K_2O each at tillering and panicle initiation stages increased straw yield. Zayed *et al.* (2007) showed that increasing basal potassium rate from 0 to 72 kg K_2O ha^{-1} significantly increased straw yield.

Nutrients uptake

Means of N, P, K and Zn uptake in grain and straw of E. Hybrid1 as affected by split application of K in 2009 and 2010 seasons are presented in Tables 7 and 8. Data show that the nutrients uptake was significantly affected by time and method of application of K in both seasons. Soil application of K alone or along with foliar spray resulted in a significant increase in N, P, K and Zn uptake in grain and straw compared with control in both seasons. Foliar application treatment of K at MT and PI stages or at MT stage alone without K as basal was superior to control treatment in N, P, K and Zn uptake in grain and straw in the two seasons. Maximum N, P, K and Zn uptake in grain was recorded by the application of K in three equal splits at basal, MT and PI stages, which was statistically higher than entire basal application or foliar spray of K separately in both seasons.

TABLE 7. N, P, K and Zn uptake in grain of Egyptian Hybrid1 as affected by split application of potassium in 2009 and 2010 seasons.

kg K_2O/fed.				N- uptake (kg/fed)		P- uptake (kg/fed)		K- uptake (kg/fed)		Zn- uptake (g/fed)	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	56.28 f	52.92 f	12.64 e	11.42 f	12.01 e	16.17 e	216.72 e	186.48 d
T_2	24	-	-	65.94 bc	65.52 cd	13.65 d	13.82 d	22.76 c	22.89 d	264.60 bc	215.46 c
T_3	8	8	8	76.02 a	80.64 a	14.99 a	17.22 a	26.42 a	28.06 a	287.28 a	264.18 a
T_4	8	8	S	73.08a	78.54 a	14.57 ab	16.88 a	25.62 ab	27.38ab	272.16 ab	259.14 a
T_5	12	12	S	76.44 a	81.06 a	14.95 a	17.22 a	26.38 a	28.10 a	274.26 ab	263.76 a
T_6	8	S	S	66.78 bc	70.14 bc	13.73 cd	14.78 c	22.93 c	24.65 c	249.90 cd	237.30 b
T_7	12	S	S	67.62 b	74.34 ab	13.82 bcd	15.83 b	23.23bc	26.12 bc	263.34 bc	248.64ab
T_8	24	S	S	75.18 a	79.38 a	14.49 abc	16.88 a	25.66 ab	27.59 ab	270.06 ab	257.88 a
T_9	-	S	-	60.48 de	59.64 de	13.52 d	13.27 de	21.88 c	22.81 d	243.18 d	218.40 c
T_{10}	-	-	S	58.80 ef	58.38 ef	13.40 de	12.73 e	17.93 d	22.05 d	233.52de	207.90 c
T_{11}	-	S	S	63.00 cd	60.48 de	13.57 d	12.98 de	22.13 c	22.22 d	249.06 cd	212.52 c

B = basal MT = med tillering stage PI = panicle initiation stage S = foliar spraying with 2% K_2O.
In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

Top dressing each of 8 or 12 kg K_2O/fed twice at basal and MT stage along with foliar K at PI stage and entire basal application along with foliar at MT and PI stages were insignificantly with application of K in three equal splits in N, P, K and Zn uptakes in grain in both seasons. However, Maximum N, P, K and Zn uptake in straw was recorded by entire basal along with foliar application of K at MT and PI stages, which was significantly higher than foliar spray of K separately or along basal application of 8 kg K_2O/fed in both seasons. The treatment containing K application twice on soil as basal and at med tillering stage, or single basal application of 24 kg K_2O/fed were insignificantly with entire basal along with foliar application of K at MT and PI stages in these traits in both seasons.

TABLE 8. N, P, K and Zn uptake in straw of Egyptian Hybrid1 at heading as

affected by split application of potassium in 2009 and 2010 seasons.

kg K_2O/fed				N- uptake (kg/fed)		P- uptake (kg/fed)		K- uptake (kg/fed)		Zn- uptake (g/fed)	
Term	**B**	**MT**	**PI**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
T_1	-	-	-	27.72 d	26.46 e	5.50 c	5.29 e	78.12 e	76.44 d	225.12 f	168.84 e
T_2	24	-	-	32.76 ab	35.70 ab	6.55 ab	7.06 ab	106.68 ab	104.58ab	272.16 ab	305.34 ab
T_3	8	8	8	31.92abc	34.44abc	6.43 ab	6.89 abc	102.90abc	103.32ab	270.06abc	291.06abc
T_4	8	8	S	31.50abc	34.02abc	6.30 ab	6.80 abc	102.90abc	100.80ab	270.48abc	289.38abc
T_5	12	12	S	32.34 ab	36.12 ab	6.55 ab	7.22 ab	106.26 ab	110.88a	274.26 ab	306.18 ab
T_6	8	S	S	30.66 bc	31.50 cd	6.13 b	6.22 cd	94.50 cd	97.44 bc	247.38 de	265.86 cd
T_7	12	S	S	31.92abc	33.18bcd	6.43ab	6.64 bc	96.6 bcd	100.38ab	263.34bcd	281.82bcd
T_8	24	S	S	34.02 a	36.96 a	6.85 a	7.43 a	112.98 a	111.72 a	287.28 a	315.00 a
T_9	-	S	-	30.24 bc	31.50 cd	6.05 b	6.26 cd	90.30 d	95.34 bc	243.18def	268.38 cd
T_{10}	-	-	S	29.4 cd	29.82 d	5.96 bc	5.88 d	89.04 d	87.36 c	233.52 ef	254.10 d
T_{11}	-	S	S	30.66 bc	31.92 cd	6.13 b	6.26 cd	95.76 cd	96.18 bc	249.06cde	268.80 cd

B = basal, MT = med tillering stage, PI = panicle initiation stage, S = foliar spraying with 2% K_2O.
In each column means followed by a common letter are not significantly different at the 5% level by DMRT.

Potassium performs many functions in plant metabolism, promoting photosynthesis, harnessing the interaction of K with N and hence could have increased the nutrient uptake (Marschner, 1995). In this connection, Surendran (2005) found that application of 50 percent K_2O each at tillering and panicle initiation stages increased N, P and K uptake. Zayed *et al.* (2007) found that the basal application of 72 kg K_2O ha^{-1} recorded the maximum values of K leaf content. Gorgy *et al.* (2009) reported that potassium application increased N and K shoot content compared with the control. Hashem (2010) found that adding half dose of K as basal along with foliar spray at panicle initiation and flowering stages recorded the maximum values of N, P, K and Zn uptake in grain and straw.

Correlation coefficients among each of N, P, K and Zn content and its grain yield as well as its straw yield were significantly positive in both seasons (Table 9). This indicates that grain and straw yield were increased by increasing N, P, K and Zn contents, which was achieved by application of K and reflected in increased nutrients uptake.

TABLE 9. Coefficients of correlation between nutrient contents and grain and straw

yields in 2009 and 2010 seasons.

Nutrient	Grain yield		Straw yield	
	2009	2010	2009	2010
N	0.71 **	0.83 **	0.69 **	0.76 **
P	0.45 *	0.86 **	0.72 **	0.71 **
K	0.85 **	0.75 **	0.82 **	0.81 **
Zn	0.57 **	0.87 **	0.79 **	0.89 **

Conclusion

The results indicated that application of K fertilizer through top dressing or foliar spray is imperative to increasing productivity of hybrid rice. Application of K_2O in three equal splits at basal, MT and PI stages or in two equal splits at basal and MT stage along with foliar at PI stage or in combination of top dressing and foliar could favourably influence the yield and uptake of nutrients. Potassium application to hybrid rice as basal could be decreased or skipped off in soils having high available K. In order to adequate supply of K during peak periods its demand by the crop; it is imperative that K can be applied in split doses with foliar spray for better rice production. However, it needs further investigation in subsequent studies, involving a greater number of hybrid rice varieties and application of K at all growth stages (tillering, panicle initiation, booting and heading) in different locations to formulate a general recommendation.

References

Ali, A. M.S. Zia, Hussain, F., Salim, M., Mahmood, I.A. and Shahzad, A. (2005) Efficacy of different methods of potassium fertilizer application on paddy yield, K uptake and agronomic efficiency. *Pakistan J. Agri. Sci.* **42** (1-2), 27-32.

Awan, T.H., Manzoor, Z., Safdar, M.E. and Ahmad, M. (2007) Yield response of rice to dynamic use of potassium in traditional rice growing area of Punjab. *Pakistan J. Agri. Sci.* **44** (1),130-135.

Black, C.A., Evans, D.D., Ensminger, L.E. and Clark, F.E. (1965) "*Methods of Soil Analysis. Part 2- Chemical and Microbiological Properties*". American Soc. of Agronomy, Inc., Publisher, Madison, Wisconsin, USA.

Brohi, A.R., Karaman, M.R., Topbas, M.T., Aktas, A. and Savasli, E. (2000) Effect of potassium and magnesium fertilization on yield and nutrient content of rice crop grown on artificial siltation soil. *Turk. J. Agric*. **24**, 429–435.

Chapman, H.D. and Parrt, P.F. (1961) "*Methods of Aanalysis for Soils, Plant and Water*". Univ. of California , Berkeley, USA.

Duncan, D.B. (1955) Multiple Range and Multiple F-tests. *Biometrcs,* **1**, 1-42.

Fageria, N.K., Baligar, V.C. and Jones, C.A. (1997) "*Growth and Mineral Nutrition of*

Field Crops". 2nd ed. Marcel Dekker, Inc., New York, NY.

Gomez, K.A. and Gomez, A.A. (1984) "*Statistical Procedures for Agricultural Research*". 2nd ed. Jahn Wiley Sons, New York, USA.

Gorgy, R.N., Zayed, B.A. and Abou Khalifa, A.A.B. (2009) Effect of split application of nitrogen and potassium to SK2047 hybrid rice. *J. Agric. Sci. Mansoura Univ*. **34** (11), 10631 – 10642.

Gobi, R., Pandian, B.J. and Kanaka, S. (2006) Evaluation of stand establishment methods and split application of N and K for hybrid rice (CORH-2) **.** *Crop Res. Hisar.* **32**(3), 275-278.

Hashem, I.M.M. (2010) Fertilization of hybrid rice plants grown under Egyptian alluvial soil conditions. *Ph.D. Thesis in Soil Sci.,* Fac. Agric., Mansoura Univ., Egypt.

Hu, H. and Wang, G.H. (2003) Influence of potassium fertilizer on nutrient accumulation and physiological efficiency of hybrid rice. *Plant Nutr. Fertilizer Sci*. **9** (2), 184-189.

Hu, H. and Wang, G.H. (2004) Nutrient uptake and use efficiency of irrigated rice in response to potassium application. *Pedosphere,* **14**(1),125–130.

Jackson, M. L. (1967) "*Soil Chemical Analysis*". pp. 144-197. Prentis Hall of India Pvt. Ltd., New Delhi.

Jayaraj, T. and Chandrasekharan, B. (1997) Foliar fertilization to enhance seed yield and quality in rice. *Seed Res.* **25**, 50–52.

Kafkafi, U., Xu, G., Imas, P., Magen, H. and Tarchitzky, J. (2001) Potassium and chloride in crops and soils: The role of potassium chloride fertilizer in crop nutrition, *IPI Research Topics No. 22.*, Inter. Potash Institute, Basel, Switzerland.

Kavitha, M.P., Balasubramanian, R., Babu, R. and Pandi, V.K. (2008) Effect of nitrogen and potassium management on yield attributes, yield and quality parameters of hybrid rice. *Crop Res. Hisar,* **35** (3),172-175.

Liu, G. D. and Liu, G.L. (1997) Genotypic differences of potassium contents of rice (*Oryza sativa* L.) seeds. *Chin. J. Rice Sci.* **11** (3), 179–182.

Manjappa, K., Kataraki, N., Kelaginamani, S.V. and Jowkin, V. (2008) Potash management in rainfed transplanted paddy in lowland rice soils. *Karnataka J. Agric. Sci.* **21**(4), 482-484.

Manzoor, Z., Awan, T.H., Ahmad, M., Akhter, M. and Faiz, F.A. (2008) Effect of split application of potash on yield and yield related traits of basmati rice. *J. Anim. Pl. Sci.* **18**(4), 120-124.

Marschner, H. (1995) "*Mineral Nutrition of Higher Plants*". 2nd ed., Academic Press, London, UK.

Mikhaael, B.B.Y. (2010) Fertilizer requirements for hybrid rice. *Ph.D. Thesis in*

Agronomy, Fac. Agric., Kafr El-Sheikh Univ., Egypt.

Narang, R.S., Mahal, S.S., Seema, B., Gosal, K.S. and Bedi, S. (1997) Response of rice and wheat to K-fertilization under maximum yield research strategies. *Envir. Eco*. **15**, 474-477.

Samrathlal, M., Surendra, S. and Shivay, Y.S. (2003) Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application in sandy clay –loam soils. *Indian J. Agri. Sci*. **73** (1), 8-11.

Surendran, U. (2005) Split application of muriate of potash and sulphate of potash on growth, yield attributes, uptake and availability of nutrients in lowland rice Cv. PY-5. *J. Agric. Sci.* **1** (2), 42-48.

Tandon, H.L.S. and Sekhon, G.S. (1988) "*Potassium Research and Agricultural Production in India*". 144 pp. Fertiliser Development and Consultation Organization, New Delhi.

Tu, J., Zhang, G., Datta, K., Xu, C., He, Y., Zhang, Q., Khush, G.S. and Datta, S. K. (2000) Field performance of transgenic elite commercial hybrid rice expressing *Bacillus thuringiensis* d-endotoxin. *Nature Biotechnology*, **18**, 1101–1104.

Watanabe, F.S. and Olsen, S.R. (1965) Test of an ascorbic acid method for determining phosphorus in water and sodium bicarbonate extracts from soils. *Soil Sci. Soc. Amer. Proc.* **29**, 677-680.

Xu, G. and Bao, S. (1995) The relationship between potassium absorption ability and root parameters of different crops. *J. Nanjing Agri. Univ*. **18**, 49–52.

Yoshida, S., Forno, D.A., Cock, J.H. and Gomoz, K.A. (1972) "*Laboratory Manual for Physiological Studies of Rice*". 2nd ed., Inter. Rice Res. Institute, Loss Banos, Philippines.

Yuan, L. P. (2004) Hybrid rice technology for food security in the world. *Fao Rice Conf.*, Rome, Italy, 12-13 February. (Available at http://www.fao.org/rice2004/en/pdf/longping.pdf)

Zayed, B.A., Elkhoby, W.M., Shehata, S.M. and Ammar, M.H. (2007) Role of potassium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. *African Crop Sci. Conf. Proc*. **8**, 53-60.

(*Received* 22/2/2011;
accepted 22/6/2011)

إستجابة الأرز الهجين لموعد وطريقة إضافة السماد البوتاسى

تامر فاروق متولى و هانى صبحى غريب*
مركز البحوث والتدريب فى الأرز بسخا – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية و *قسم المحاصيل – كلية الزراعه – جامعه كفر الشيخ – كفر الشيخ- مصر.

أجريت تجربتان حقليتان بالمزرعة البحثية بمركز البحوث و التدريب في الأرز بسخا– كفر الشيخ، فى موسمى ٢٠٠٩ و٢٠١٠، لدراسة إستجابة صنف الأرز المصرى "هجين١ " لمواعيد إضافة السماد البوتاسى (على الشراقى ، وعند منتصف مرحلة التفريع، وعند بدء نشوء الدالية) وطرق الإضافة (إضافة أرضية، والرش الورقى). تم إضافة السماد البوتاسيوم للأرض بالمعدل الموصى به٢٤ كجم بو٢ أ / فدان على دفعة واحدة أو عدة دفعات. واستخدم محلول ٢٪ بو٢ أ في الرش الورقى لتعويض النقص فى معدل البوتاسيوم. تضمنت الدراسة ١١ معاملة عبارة عن بعض التواليف بين الإضافة الأرضية (كجم بو٢ أ / فدان) والرش الورقى فى مواعيد الإضافة الثلاثة على الترتيب (١) بدون تسميد بوتاسى ، (٢) ٢٤+٠+٠ ، (٣) ٨+٨+٨ ، (٤) ٨+٨+رش ، (٥) ١٢+١٢+رش ،(٦) ٨+ رش+رش ،(٧) ١٢+ رش+رش ،(٨) ٢٤+ رش+رش ، (٩) ٠+ رش+٠ ،(١٠) ٠+٠+رش ، (١١) ٠+ رش+رش، على الشراقى ، وعند منتصف مرحلة التفريع، وعند مرحلة بدء نشوء الدالية على الترتيب.

أظهرت النتائج أن إضافة البوتاسيوم على الشراقى أو بالرش الورقى مرتين كل منها عند منتصف مرحلة التفريع ومرحلة بدء نشوء الدالية أدت إلى زيادة معنوية فى إرتفاع النبات والوزن الجاف بالمتر المربع عند إكتمال الطرد. أدى استخدام البوتاسيوم سواء بالإضافة الأرضية أو الرش الورقى كل منها على حده أو معا إلى زيادة معنوية فى عدد السنابل بالمترالمربع، وزن السنبلة، طول السنبلة، عدد الحبوب الممتلئة بالدالية، ووزن ١٠٠٠ حبة، محصول الحبوب، كمية العناصرالغذائية الممتصة بالحبوب (نيتروجين، فوسفور، بوتاسيوم، زنك) مقارنة بمعاملة المقارنة (بدون إضافة بوتاسيوم). سجلت تجزئة السماد البوتاسى ٢٤ كجم بو٢ أ / فدان على ثلاث دفعات متساوية أعلى قيم لمحصول حبوب ومكوناتة و كمية العناصرالغذائية الممتصة بالحبوب بالمقارنة بإضافة هذه الكمية دفعة واحدة على الشراقى أو الرش الورقى عند منتصف التفريع ومرحلة بدء نشوء الدالية كل منهما على حده . إستخدام البوتاسيوم على الشراقى إلى جانب استخدامه نثرا أو بالرش الورقى فى مرحلتى منتصف التفريع ومرحلة بدء نشوء الدالية لم يختلف معنويا عن إستخدامة على ثلاث دفعات متساوية فى محصول الحبوب ومكوناته وكمية العناصر الممتصة بالحبوب. بينما إستخدام ٢٤ كجم بو٢ أ / فدان على الشراقى مع الرش الورقى فى مرحلتى منتصف التفريع ومرحلة بدء نشوء الدالية إدى إلى الحصول على أعلى محصول قش و كمية العناصرالغذائية الممتصة بالقش . ولم تؤثر معاملات رش البوتاسيوم منفرده على محصول القش عن معاملة المقارنة. ولم تختلف كل المعاملات التى تتضمن إضافة البوتاسيوم على الشراقى فقط عن معاملة استخدام كل الكمية على الشراقى مع الرش الورقى فى محصول القش.

ويستنتج من نتائج هذه الدراسة أنة يمكن استخدام السماد البوتاسى بمعدل ٢٤ كجم بو٢ أ/فدان على ثلاث دفعات متساوية ٨+٨+٨ ، ٨+٨+رش، ١٢+رش+رش، ٨+رش +رش على الشراقى وعند منتصف مرحلة التفريع ومرحلة بدء نشوء الدالية, على التوالى، لتعظيم انتاجية محصول صنف الأرز هجين مصرى ١ بمحافظة كفرالشيخ.