GROWTH AND YIELD OF RICE AS INFLUENCED BY POTASSIUM AND KINETIN

By

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DECLARATION

I hereby declare that this thesis entitled **"Growth and yield of rice as influenced by potassium and kinetin"** is a bonafide record of research work done by me during the period of my P.G. course and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of this or any other University or Society.

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1st July 1988

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SAKEENA, I.

CERTIFICATE

Certified that this thesis entitled **"Growth and yield of rice as influenced by potassium and kinetin"** is a bonafide record of research work done independently by Sakeena, I. under my guidance and supervision and that this has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

AICARP	All India Co-ordinated Agronomic Research Project
@	At the rate of
cm	Centimetre
CSRC	Cropping Systems Research Centre.
DAF	Days after flowering
DAT	Days after transplanting
F	Flowering
g	gram
HI	Harvest index
ha	hectare
kg	kilogram
KAU	Kerala Agricultural University
ppm	parts per million

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INTRODUCTION

1. INTRODUCTION

Rice, the premier cereal crop of India occupies an area of 42 million hectares contributing 42% of the country's food grain production. Rice production technology in the recent past has been undergoing spectacular changes with the introduction of high yielding varieties. The productivity of the crop depends not merely on the CO_2 fixing capacity of the plant but also on the flow of photosynthates from the source to the sink. Increased biomass productivity has little meaning unless it is in the form of economic product. In other words, harvest index assumes paramount importance in crop production. The yield physiology is thus to be studied analysing the partitioning of photosynthetic products between the source and the sink. Development of new technology to improve the harvest index or partition the photosynthates more to the economic sink either by management practices or by genetic manipulation is thus a matter of interest to the researchers.

The role of potassium on enzyme activation, photosynthesis and assimilate translocation is well known. Potassium induces drought tolerance and imparts resistance to pest and diseases (Singh and Tripathi, 1979; Mengel and Kirkby, 1983). Potassium plays a key role in increasing the yield of crops and in improving the quality of crop produce (Goswami and Khera, 1981). Being a comparatively cheaper element, even higher doses of potassium application can be thought of if it can hasten the transport of synthates to the grain which otherwise would accumulate in the source.

Leaves being the main sites of photosynthesis, an increase in the longivity of upper leaves by treatment with hormones may delay the leaf senescence and increase the grain yield (Yoshida, 1972; Evans 1975). Biswas and Choudhuri (1980) reported that there is possibility of augmenting the grain yield by prolonging the period of mobilization of metabolites from leaves to grains as a result of hormone treatments. Mishra and Pradhan (1973) reported that kinetin, a plant growth hormone act as a potent senescence arrestor. Kinetin influences the direction of transport of organic metabolites and minerals to the sink (Krishnamoorthy, 1981).

Lots of work have been done by researchers to study the main effect of potassium on the growth and yield of rice. Few reports on the effect of kinetin on rice is also traceable in literature. But no effort seems to have been made so far to study the differential influence of potassium due to kinetin application. Hence the present study was undertaken with the following objectives.

1. To study the differential influence of potassium due to kinetin application on growth and yield of rice.

2. To study the partitioning of carbohydrates and proteins between the source and sink of rice as influenced by potassium, kinetin and their interactions.

3. To examine the possibility of influencing the harvest index of rice by the combined application of potassium and kinetin.

4. To study the economics of rice cultivation as influenced by potassium and kinetin application.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A brief review of research work done on the effect of potassium and kinetin on the growth, yield, quality and nutrient uptake of rice is presented below.

A. Role of potassium in plants

The nutrient ion K^+ is omnipresent in the plant system and is linked with almost all phenomena of the physiology of the plant. It is possible to attribute a number of functions to potassium, but hardly possible to endow it with a specific role. It intervenes in the following domains of plant physiology viz., photosynthesis, enzyme activation, metabolism of carboydrates, organic acids, fats and nitrogeneous compounds, protein systhesis, water economy, cell elongation, resistance to drought, frost, lodging, pests, diseases and physiological disorders (Balram et al. 1977; Singh and Tripathi, 1979).

B. Effect of Potassium

1. Growth characters

a. Height of plant

Vijayan and Sreedharan (1972) observed significant increase in plant height with increase in the levels of potassium from 20 to 80 kg/ha in rice variety IR 8. Similar beneficial effects of potassium to increase the plant height in rice were reported by many workers (Venkatasubbaiah et al. 1982; Xu et al. 1984)]

b. Tiller production

{Kulkarni et al. (1975) reported that the effect of potassium was significant and positive on tiller production in rice. Singh and Singh (1979) obtained increased tillering with application of potassium upto 60kg K_2O/ha Linbao (1985) also reported similar effect of potassium on tillering in rice.}

c. Dry matter production

Hoang (1974) obtained an increase in dry matter production with potassium application upto 75 Kg K_2O/ha. Increase in dry matter production with increase in the levels of potassium upto 50 kg K_2O/ha was observed by Mishra (1980). Enhanced dry matter production due to potassium application upto 60 kg K_2O/ha was reported by Hati and Misra (1983). Senthivel and Palaniappan (1985) also reported similar effects of potassium on dry matter production.

2. Physiological characters.

a. Leaf area index

Increase in leaf area due to potassium application in rice was noticed upto 75 kg K_2O/ha by Hoang (1974). A positive correlation between potassium application and leaf area index in rice was observed by Mandal and Dasmahaptra (1983).

b. Chlorophyll content

Hoang (1974) observed increase in chlorophyll content of flag leaf due to potassium application. Potassium checks the chlorophyll degradation and promotes the synthesis of both chlorophyll a and b. Ray and Choudhuri (1980) after detailed study concluded that the application of potassium increased the chlorophyll content. Das and Sarkar (1981) reported that potassium increased the retention of chlorophyll in the flag leaf and delayed senescence during the active grain filling stage.

c. Carbohydrate content

In trails with rice grown on meadow chernozem soil, Rymer (1973) found that application of 90 kg K_2O/ha increased starch content by 2.4 per cent. Haeder and Mengel (1974) showed that increasing potassium supply accelerated CO_2 uptake and improved the translocation of carbohydrates to the ear. Mishra (1980) reported that carbohydrate metabolism of rice is affected by varying levels of potassium supply. He found that increasing the levels of potassium helps in building up starch.

Potassium stimulates building up and translocation of carbohydrates in rice plant (Roy et al. 1980). Potassium influences many of the processes that are important for the formation of yield in plants such as water economy, the synthesis of carbohydrates and transport of assimilates (Mengel and Kirkby, 1983). Vil'Gel'M (1986) reported that potassium applied at any stage of growth in rice increased the starch and soluble carbohydrate content in the grains.

d. Protein content

Potassium is involved in the formation of proteins through the polymerisation of amino acids and other primary units in plants (Webster and Warner, 1954). They further reported that coupling of certain amino acids require potassium in the form of peptide, indicating its importance in protein synthesis. According to Chavan and Magar (1971) application of 40 kg K_2O/ha increased the protein content of rice compared to 20 kg K_2O/ha. Rymer (1973) reported the application of 90 kg K_2O/ha increased grain protein content by 1.5 percent.

Haeder and Mengel (1974) observed a favourable effect of potassium on crude protein content of wheat grains. Agarwal (1978) noticed an increase in the crude protein content of grain from 9.62 to 10.17 per cent with increase in the level of potassium from 0 to 120 kg K_2O/ha. Ray and Choudhuri (1980) obtained higher protein content in plants treated with potassium than in the untreated control. Higher levels of potassium resulted in a decrease in total nitrogen and soluble nitrogen content of grains but an increase in protein nitrogen (Mishra, 1980)

Potassium increased the rate of translocation of amino acids to the grain and the rate of protein formation (Mengel et al. 1981). According to Vil'Gel'M (1986) application of potassium markedly increased protein content of grains.

3. Nutrient uptake

Muthuswamy et al. (1974) reported that higher levels of potassium application increased the uptake of N,P & K by rice. Esakkimuthu et al. (1975) observed that nitrogen uptake was more due to potassium application. Mengei et al. (1976) reported that N, P and K uptake and their translocation were highest with application of 60 kg K_2O/ha. Koch and Mengel (1977) showed that potassium application increased N uptake of rice and the N content in the grain.

Reddy et al. (1978) found that N uptake increased with increase in the appplication of potassium from 50 to 100 kg K_2O/ha. Steineck and Haeder (1980) propounded that nitrogen utilization by the rice plant is determined by the potassium supply. The total uptake and percentage translocation of N, P and K by rice increased significantly with increasing levels of potassium (Singh and Singh, 1987).

4. Yield components and yield

a. Number of panicles per m^2

Kulkarni et al.(1975) observed that potassium application increased the number of productive tillers in rice. Similar effects of potassium were also observed by Padmaja (1976); Sahu and Ray (1976); Venkatasubbaiah et al. (1982) and Mandal and Dasmahapatra (1983).

b. Length of panicle

Singh and Singh (1979) reported that application of 60 kg K_2O/ha in splits increased panicle length in rice. Similar effects of potassium on panicle length was reported by Varma et al. (1979) and Xu et al. (1984).

c. Number of spikelets per panicle

Vijayan and Sreedharan (1972) reported increase in the number of spikelets per panicle with increase in the level of potassium from 20 to 80 kg K_2O/ha. Uexkull (1982) also reported similar effect of potassium on number of spikelets per panicle.

d. Percentage of filled grains

Filled grain percentage was more in plants supplied with potassium @ 50 kg K_2O/ha compared to control (Venkatasubbaiah et al. 1982). In potassium deficient soil, K application increased the number of filled grains by 5 to 15 per cent (Linbao, 1985) and this trend was reported by many other workers (Uexkull, 1976; Varma et al. 1979 and Xu et al. 1984).

e. Thousand grain weight

Singh and Singh (1979) after detailed study on rice, concluded that application of 60 kg K_2O/ha increased the thousand grain weight compared to control. Sreekumaran (1981) also reported similar results. Potassium application is positively correlated to grain weight (Mandal and Dasmahapatra 1983; Venkatasubbaiah et al. 1982 and Xu et al. 1984) The thousand grain weight increased by 0.5 to 4.0g (Linbao, 1985) with increasing levels of potassium application.

f. Grain yield.

Application of potassium was not considered essential in the past in view of the K richness of Indian soils. However, with the introduction of fertilizer responsive high yielding rice varieties and intensive cropping, response to potassium application has been consistantly observed (Kemmler, 1971).

The grain yield of rice increased with increase in level of potassium (Robinson and Rajagopal, 1977) and the effect was linear upto 60 kg K_2O/ha Agarwal, (1980) observed significant increase in the rice yield by the application of K_2O/ha upto 80 kg/ha. Potassium application increased the rice yield in lateritic soils under submergence and it was even more in soils which were subjected to wetting and drying (Nad and Goswami, 1981). Venkatasubbaiah et al. (1982) observed highly significant increases in grain yield due to applied potassium in potassium depleted soil.

Results of the experiment conducted at Jorhat showed that application of 40 to 80 kg K_2O/ha could increase the grain yield of rice considerably over the control (Barthakur et al. 1983). Gurmani et al. (1984) reported a significant increase in grain yield and increase in the level of potassium from 0 to 83 kg K_2O/ha. Data from the All India Co-ordinated Agronomic Research Project (AICARP) for a large number of experiments on cultivators field all over the country showed a progressive increase in the response of rice to applied potassium.

The yield response of rice in most soils was significant at 40 and 60 kg K_2O/ha (Bhargava et al. 1985). The percentage increase in yield upto a maximum of 185 has been obtained by Patiram and Prasad (1987) due to potassium application.

g. Straw yield

Singh et al. (1976) observed that application of 120 kg K_2O/ hectare gave the highest straw yield. Singh and Prakash (1979) reported an increase in straw yield with increase in level of potassium from 0 to 60 kg K_2O/ha. Highly significant increase in yields of grain and straw were observed due to applied potassium by Venkatasubbaiah et al. (1982). According to them, the effect of potassium application was more on grain yield compared to straw yield.

5. Economics of potassium nutrition

Misra et al. (1976) reported that potassium application at 50 kg K_2O/ha gave a marginal return of Rs.614/- per hectare. According to Hati and Misra (1983), the economic optimum dose of potassium for rice on a soil of low potassium content was 54 kg K_2O/ha. Data from the AICARP experiments revealed that in majority of the trials the additional gain with 60 kg K_2O/ha was more than Rs.600/- per hectare (Bhargava et al. 1985)

The review of literature on the effect of potassium on rice presented in the foregoing section clearly reveals that potassium application has got a significant positive effect on the growth, yield and nutrient uptake of rice. It ranged from 20 to 60 kg K_2O/ha in soils of low to medium potassium content.

B. Effect of Kinetin

Cytokinins are plant hormones which cause cell division in plants (Krishnamoorthy, 1981). Cytokinins have ben found to influence a broad array of physiological processes in plants like promotion of cell division, development of embryos during seed development, expansion of cells and cotyledons, delaying senescence etc. Cytokinins influence the direction of transport of organic metabolites and minerals and their accumulation in the cells (Krishnamoorthy, 1981). The metabolites are preferentially translocated to developing fruits and seeds which incidentally are also known to contain cytokinin (Krishnamoorthy, 1981). Kinetin and benzyladenine are synthetic cytokinins. Chemically, kinetin is 6-furfurylamino purine. Kinetin has been beneficially used for modifying growth, increasing the yield and improving the quality of many cereals (Krishnamoorthy, 1981).

A brief review of work done on the effect of kinetin on the growth, yield, quality and nutrient uptake of cereals is presented below.

1. Growth characters

The effect of kinetin on the growth of tiller buds and apical buds of rice seedlings grown on agar medium with or without kinetin was investigated by Hanada (1976). It was found that kinetin application promoted tiller bud growth. Langer et al. (1973) reported that application of kinetin increased the number of tillers in wheat. In tests with Dornburg naked barley, Labes and Ryschka (1980) obseved that tillering in barley was stimulated by kinetin. Ismagilov (1981) reported that application of 0.5 ppm kinetin increased germination and fresh and dry weight of buck wheat.

2. Physiological characters

a. Leaf area index

Seed treatment of spring wheat with 10 ppm kinetin increased the total and flag leaf area (Herzog and Geisler, 1977). Foliar spray of kinetin at flowering increased the leaf area index from 2.69 to 4.81 in rice (Biswas and Choudhuri, 1978). Ismagilov (1981) reported that foliar applciation of 0.5 ppm kinetin increased the leaf area of buck wheat. Kinetin spray at 10 ppm at 10 days after flowering enhanced functional leaf area in rice (Debata and Murty, 1981).

b. Chlorophyll content

Seed treatment with 10 ppm kinetin resulted in an increase in chlorophyll content of spring wheat leaves (Herzog and Geisler, 1977). Kinetin increased the chloroplast activity in maize (Dushkova et al. 1977). Based on invitro and invivo studies, Misra and Biswal (1980) reported that kinetin application inhibited chlorophyll less during ageing of wheat chloroplasts. Kinetin at 10 ppm sprayed ten days after flowering delayed leaf senescence by increasing leaf chlorophyll content in rice (Debata and Murty, 1981).

Kinetin spray of wheat increased the chlorophyll content and green area of the flag leaf, especially during senescence, apparently by maintaining the nucleic acid content (Herzog, 1981). Investigations by Chernavina et al. (1981) revealed that the chlorophyll content in leaves of cereals grown under different nutrient conditions was higher due to kinetin treatment. Takaki (1982) observed that incubation of leaf discs of maize in solution containing 10^{-5}M kinetin prevented the degradation of chlorophyll and thus retarded senescence.

Hou (1983) reported that application of kinetin after flowering delayed leaf senescence and maturity by 2-3 days. He further reported that yield increase caused by Kinetin may be due to the increased longivity of flag leaf (delayed leaf senescence) and increased transport of photosynthates from the source to the sink. Spraying 100 day old rice plants with kinetin resulted in higher total chlorophyll content (Ray et al. 1983)

c. Carbohydrate content

Under the influence of kinetin, the accumulation of monosaccharides and disaccharides in wheat grain was markedly increased (Ismagilov, 1981). Studies conducted by Santokh and Gurbaksh (1982) showed that kinetin application caused maximum accumulation of starch in the rice grain.

d. Protein content

Erion (1979) reported that cytokinins mediate regulatory control over protein synthesis. The consumption of protein nitrogen by buck wheat seedlings was markedly activated during the first few days of growth under the influence of kinetin (Ismagilov, 1981). Spraying 100-day old rice plants with 100 ppm kinetin significantly increased the protein levels in grain compared to untreated plants (Ray et al. 1983). Ray and Choudhuri (1984) observed that post flowering treatment of rice with 100 ppm kinetin prevented the decline in protein contents in leaves during senescence. A foliar spray of 10ppm kinetin ten days after flowering increased the protein content of grains in rice (Debata and Murty, 1984).

3. Nutrient uptake

Yoshida and Oritani (1979) reported that cytokinin promoted uptake of ammonium nitrogen by roots. Kinetin produced a pronounced effect on grain filling as well as on ^{32}P mobilization from individual leaf to grains (Ray and Choudhuri 1981). Simpson et al. (1982) concluded that cytokinins affect the pattern of nitrogen uptake and translocation in wheat.

4. Yield components and yield

Aufhammer and Solansky (1976) reported that kinetin spray during grain filling increased the test weight and yield of barley. Application of 100 ppm kinetin at post flowering stage increased the rice yield by increasing the number of panicles per m^2 and number of fertile spikelets per panicle, (Biswas and Choudhuri, 1977). They also observed that kinetin enhanced the export of assimilates to the panicle.

Studies conducted by Krishnayya and Murthy (1979) revealed that a foliar spray of 10ppm kinetin at flowering increased rice yields by 9 and 32 per cent in the two cultivars Cauvery and CR 143. Kinetin produced a pronounced effect on grainfilling and increased grain yield of rice (Ray and Choudhuri, 1981). According to Debata and Murty (1981) foliar application of 10 ppm kinetin at 10 days after flowering increased the panicle weight in rice.

Kinetin spray (10 ppm) at anthesis and again one week later significantly increased the number of grains per panicle, percentage of filled grains, 1000 grain weight and yield of rice (Santokh and Gurbaksh, 1982; and Gurbaksh et al. 1984). Application of 100 ppm kinetin at post flowering stage significantly increased the number of spikelets per panicle, the number of panicles per m^2, the percentage of filled grains, panicle weight, the grain yield as well as the harvest index in rice (Ray et al. 1983).

Murthy and Murthy (1984) observed that 10 ppm kinetin at post flowering stage decreased spikelet sterility in rice by 22.5 per cent. Application of 100 ppm kinetin to the flag leaf of rice at post flowering stage delayed leaf senescence and increased grain yield, grain: straw ratio and 1000 grain weight (Biswas and Mondal, 1986).

It is evident from the review presented in the foregoing section that kinetin application has got a positive effect on the growth, nutrient uptake and yield of rice. Majority of the studies revealed that 10 ppm kinetin spray at post flowering stage was most effective for growth and yield of rice.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment was conducted during summer 1987 at CSRC, Karamana to study the effect of potassium, kinetin and their interactions on the growth, yield and nutrient uptake of rice. The details of the materials used and the methods followed are presented in this chapter.

Materials

a. Experimental site

The experiment was conducted at the Cropping Systems Research Centre, Karamana, Trivandrum. The farm is situated at 8.5° North latitude and 77.9° East longitude at an altitude of 29m above mean sea level.

b. Soil

The soil of the experimental area was sandy loam, acidic in reaction, low in CEC with medium range of organic carbon, low in available nitrogen and potassium and medium in available phosphorus. The physico-chemical properties of the soil are presented in Table 1.

Table 1. Physico-chemical properties of the soil.

Sl. No.	Parameter	Depth in cm 0 - 15	15 - 30	Composite sample	Remarks
1.	Soil texture	Sandy loam	sandy loam	Sandy loam	
2.	Sand (%)	-	-	74.28	
3.	Silt (%)	-	-	8.73	
4.	Clay (%)	-	-	17.87	
5.	pH	4.8	4.8	4.5	acidic
6.	EC (dS/m)	0.01	0.02	0.016	safe
7.	CEC (c mol (p^+)/kg)	6.82	8.01	9.41	
8.	Organic carbon (%)	1.05	0.83	0.51	Medium
9.	Available N (kg/ha)	165.0	168.5	156.4	Low
10.	Available P_2O_5 (kg/ha)	27.1	26.9	26.3	Medium
11.	Available K_2 (kg/ha)	127.6	121.2	124.4	Low

c. Meteorological parameters

The experimental site enjoys a humid tropical climate. The data on various weather parameters (rainfall, mean maximum and minimum terperatures and relative humidity) during the cropping period are given in Appendix I and graphically presented in Fig.1. The mean maximum and minimum temperature during the cropping period ranged from 30.9°c to 33.4°c and 23.4°c to 25.5°c respectively. The mean relative humidity ranged from 64 to 80 per cent. The monthly rainfall ranged from trace to 196.5mm. A total of 387.7 mm rainfall was received during the cropping period.

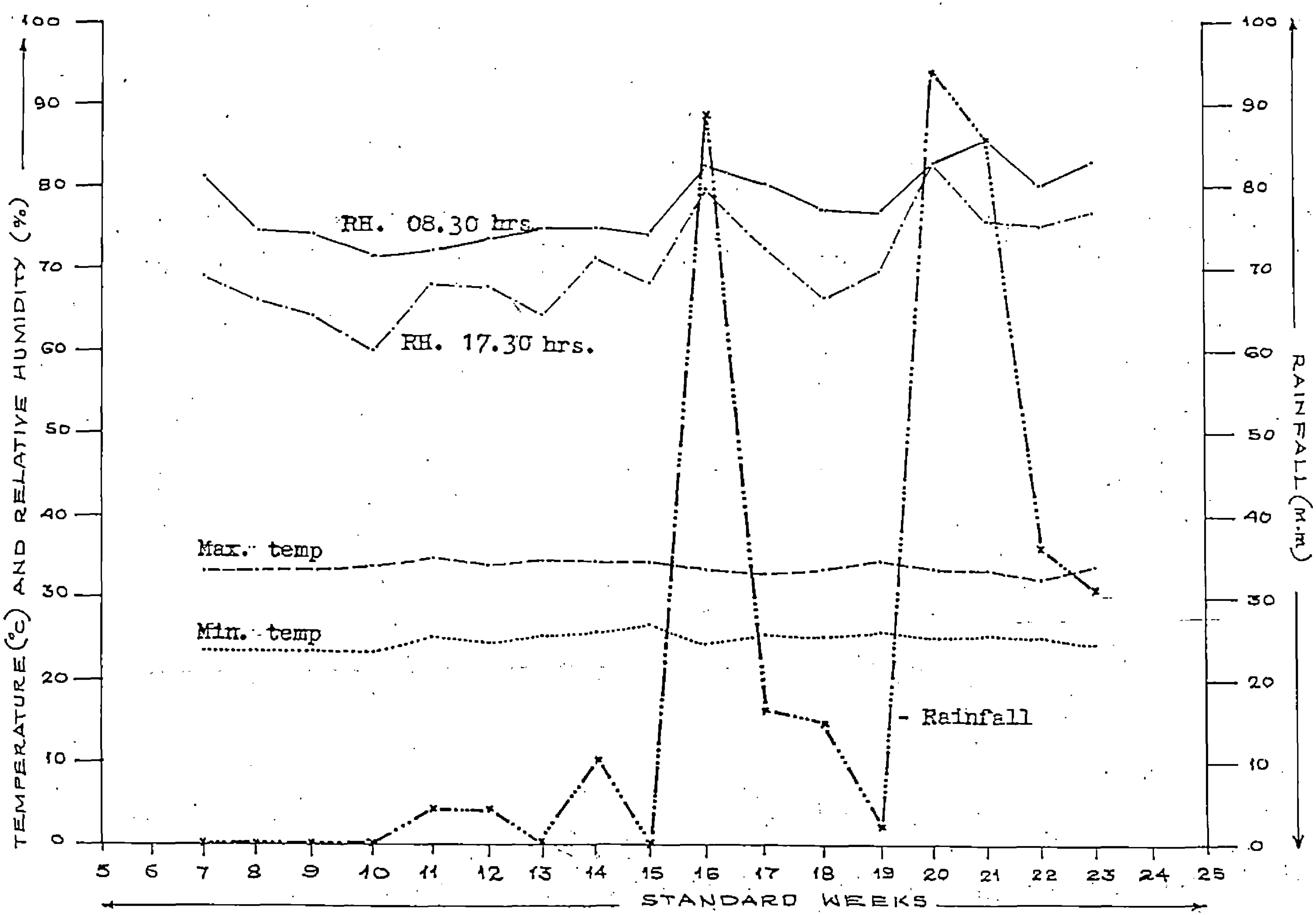
d. Season

The experiment was conducted during 1987 from 17th February to 6th June.

e. Variety

The variety used for the study was Triveni, a cross between Annapoorna and PTB-15. It is a dwarf photoinsensitive, short duration (95-105 days) variety. It has got special features like long bold and white grains with high stability in yield. The seed for the experiment was obtained from the CSRC, Karamana.

FIG. 1. WEATHER CONDITIONS DURING THE CROPPING PERIOD



f. Fertilizers used

The fertilizers used for the experiment were Urea 46 per cent N, Super phosphate 16.5 per cent P_2O_5 and Muriate of potash 58 percent K_2O.

g. Kinetin

Kinetin, a growth regulator for the experiment was obtained from the Central Scientific Supplies Company Limited, Trivandrum. Chemically kinetin is 6-Furfurylamino purine, a derivative of the nitrogen base adenine. Kinetin is effective in stimulating cell division.

Methods

a. Treatments

The treatments consisted of a factorial combination of 4 levels of potassium and 4 levels of kinetin. Altogether there were 16 treatment combinations.

i) Levels of potassium

1. K_0 - 0 kg K_2O/ha
2. K_1 - 17.5 kg K_2O/ha
3. K_2 - 35 kg K_2O/ha (recommended dose in the region for the test variety)
4. K_3 - 70 kg K_2O/ha

ii) Levels of kinetin (Bioregulant)

1. B_0 - Water spray
2. B_1 - 10 ppm kinetin spray at flowering
3. B_2 - 10 ppm kinetin spray 10 days after flowering.
4. B_3 - 10 ppm kinetin spray at flowering and again at 10 days after flowering

Note: The notation 'B' was given to indicate levels of kinetin denoting the term Bioregulant.

b. Design and Lay out

The 4 x 4 factorial experiment was laid out in a randomised block design with 3 replications. The lay out plan is presented in Fig.2. The gross plot size was 4 x 3 m and in total there were 48 plots. The spacing adopted for planting was 15 x 10 cm. Two rows of plants were left on all sides as border rows. Thus the net plot size was 3.4 x 2.6 m.

c. Cropping history of the main field

The experimental area was under bulk crop of rice during the previous seasons.

d. Details of cultivation

i) Land preparation

The selected main field was ploughed twice and levelled, and plots of 4 x 3 m were laid out with bunds of 40 cm width around.

FIG. 2 LAY-OUT PLAN – RANDOMISED BLOCK DESIGN

R1				R2				R3			
K_2B_2	K_1B_1	K_3B_3	K_1B_0	K_1B_3	K_3B_1	K_0B_1	K_0B_3	K_0B_2	K_2B_2	K_1B_1	K_3B_3
K_0B_2	K_0B_3	K_3B_2	K_0B_0	K_0B_0	K_1B_1	K_1B_2	K_1B_0	K_2B_3	K_1B_0	K_3B_0	K_0B_3
K_3B_0	K_0B_1	K_2B_3	K_1B_3	K_0B_2	K_3B_3	K_2B_1	K_2B_2	K_2B_0	K_1B_2	K_2B_1	K_1B_3
K_1B_2	K_3B_1	K_2B_1	K_2B_0	K_2B_3	K_2B_0	K_3B_2	K_3B_0	K_3B_1	K_0B_1	K_0B_0	K_3B_2

TREATMENTS

K_0 - 0 kg K_2O / ha
K_1 - 17.5 kg K_2O / ha
K_2 - 35 kg K_2O / ha
K_3 - 70 kg K_2O / ha

B_0 - WATER SPRAY
B_1 - 10 ppm KINETIN SPRAY AT FLOWERING
B_2 - 10 ppm KINETIN SPRAY AT 10 DAYS AFTER FLOWERING
B_3 - 10 ppm KINETIN SPRAY AT FLOWERING AND AGAIN 10 DAYS AFTER FLOWERING

Main and sub irrigation channels were provided. Individual plots were again puddled and perfectly levelled. Eighteen day old Triveni seedlings were transplanted and the crop was raised following standard procedures and techniques as per the package of practices recommendations of Kerala Agricultural University.

ii) Application of fertilizers

Nitrogen @ 70 kg N/ha was applied half as basal and half at panicle initiation stage. Phosphorus @ 35 kg P_2O_5/ha was applied as a single dose at transplanting. Potassium as per treatments was applied half at transplanting and half at panicle initiation stage.

iii) Application of kinetin

Aqueous solution of 10 ppm kinetin (10 mg/l) was prepared by dissolving it first in ethanol and then in water. The solution was sprayed with a hand sprayer over the crop as per treatment. A total of 200 litres of solution was used per hectare. The control plots were sprayed with water.

iv) Maintenance of the crop

Gap filling was done on the 7th day after transplanting. The crop was handweeded on the 15th and 30th days after transplanting. The general stand of the crop was good. Five centimetre water was maintained in the field continuously, and the water was cut off 10 days prior to harvest. Water control was effective to avoid any possible loss of the nutrients. Need based plant protection measures were undertaken..

v) Harvest

The border rows were harvested separately and thereafter the crop in the net area of the individual plots were harvested, threshed, cleaned, dried, winnowed and grain yield at 14 percent moisture was recorded. The weight of the sun-dried straw was also recorded.

Observations.

1. Growth characters

Two sample units of 2 x 2 hills were randomly selected in each plot as suggested by Gomez (1972) and the following periodical observations were recorded.

1.1. Height of plant

At 30 and 60 DAT the height of plant was measured from the base to the tip of the topmost leaf. At harvest, the height was recorded from the base of the plants to the tip of longest panicle and the mean height was computed and expressed in centimetres.

1.2. Number of tillers per m^2

The tillers from two 2 x 2 hill sampling units were counted at 30 and 60 DAT and the number of tillers per m^2 was calculated.

1.3. Dry matter production

Dry matter production was estimated at 30 and 60 days after transplanting and at harvest. Four samples hills were randomly selected, uprooted, washed and sun-dried. The samples were oven-dried at a temperature of 80± 5°c to constant weight and the dry matter production was calculated and expressed in kg/ha. At harvest the sum total of grain yield and straw yield was taken as the total dry matter production.

2. Physiological characters

2.1. Leaf area index

Leaf area index was computed at flowering stage. Four sample hills were randomly selected in each plot and the number of tillers were counted in each hill. The length and maximum width of leaves in the middle tiller of all the sample hills were measured separately and the leaf area was computed based on length-width method.

Leaf area = K x L x W where

'K' is the adjustment factor (0.75), 'L' is the length and 'W' is the maximum width. Thereafter the leaf area per hill and leaf area index were calculated using the following formulae.

Leaf area/hill = Total leaf area of middle tiller x total number of tillers.

$$\text{Leaf area index} = \frac{\text{Sum of leaf area per hill of 4 sample hills } (cm^2)}{\text{Area of land covered by 4 hills } (cm^2)}$$

2.2. Chlorophyll content

The total chlorophyll content of flag leaf at 15 and 25 days after flowering (DAF) was analysed spectrophotometrically by the method suggested by Arnon (1949).

2.3. Carbohydrate content

The carbohydrate content of leaf, sheath, culm and panicle at harvest were determined separately by the method suggested by Aminoff et al. (1970)

2.4. Carbohydrate yield

The carbohydrate yield of leaf, sheath culm and panicle was worked out by multiplying the carbohydrate content of the samples with the respective dry weight and expressed in kg/ha. Total carbohydrate yield was taken as the sum of the carbohydrate yield of leaf, sheath culm and panicle.

2.5. Protein content

The total N content of leaf, sheath, culm and panicle at harvest was analysed by modified microkjeldahl method (Jackson, 1967) and the protein percentage was computed by multiplying the N content with the factor 6.25 (Simpson et al. 1965)

2.6. Protein yield

The protein yield of leaf, sheath, culm and panicle was computed by multiplying their protein percentage with respective dry weights and expressed in kg/ha. Total protein yield was taken as the sum of protein yield of leaf, sheath, culm and panicle.

3. Uptake of Nitrogen, Phosphorus and Potassium

The total uptake of nitrogen, phosphorus and potassium at harvest was calculated as the product of the content of these nutrients in the plant samples and the respective dry weight and expressed in kg/ha.

4.Yield attributes and yield

4.1. Number of panicles per m^2

The total number of panicles from the 8 sample hills was counted and the number of panicles per m^2 computed.

4.2. Length of panicle.

The length of the middle panicle of each hill was measured from neck to the tip of panicle and mean length computed.

4.3. Number of spikelets per panicle

The total number of spikelets in all the panicles from 8 hills were counted and the mean number of spikelets per panicle was worked out.

4.4. Number of filled grains per panicle

The main culm panicles from the 8 hills were threshed and the number of filled grains (f) and the weight of filled grains (w) were determined. The rest of the panicles from all the 8 hills were also threshed and the weight of unfilled grains (W) was recorded. From these data, the number of filled grains per panicle was calculated using the following formula suggested by Gomez (1972).

Number of filled grains per panicle $= \frac{f}{w} X \frac{W + w}{p}$

Where 'P' is the total number of panicles from all the hills.

4.5. Percentage of filled grains

The total filled and unfilled grains from the panicles were separately counted and the percentage of filled grains was recorded.

4.6. Thousand grain weight

From the values obtained for calculating the number of filled grains per panicle, thousand grain weight was calculated and adjusted to 14 per cent moisture using the following formula proposed by Gomez (1972)..

Thousand grain weight $= \frac{100 - M}{86} X \frac{W}{f} X 1000$

M = the moisture content of filled grains

4.7. Grain yield

Grain yield was recorded from the net area, weight adjusted to 14 per cent moisture and expressed in kg/ha.

4.8. Straw yield

Straw obtained from the net plot was uniformly sun dried, weighed and expressed in kg/ha.

4.9. Harvest index

Harvest index was calculated by dividing the weight of grains (economic yield) with the total weight of grain and straw (biological yield).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

5. Economics of cultivation

The economics was worked out based on the following assumptions.

	Rs.	Ps.
1. Cost of cultivation of rice per hectare excluding the cost of treatments	4500	00
2. Cost of 1 kg K_2O	2	00
3. Cost of 1 g kinetin	200	00
4. Price of 1 kg paddy	2	00
5. Price of 1 kg straw	0	50

The net income and net return per rupee invested were calculated as follows.

Net income (RS./ha) = Gross income - Total expenditure

$$\text{Net return per rupee invested (Rs.)} = \frac{\text{Net income}}{\text{Total expenditure}}$$

6. Statistical analysis

As the treatment kinetin spray was imposed only at flowering, the observations upto 60 DAT were analysed by following the 2 way classificatory analysis with multiple observations (equal number) per cell. The data relating to different observations taken at harvest were statistically analysed applying the analysis of variance technique for factorial experiment in randomised block design (Snedecor and Cochran, 1967). Important correlations were also worked out.

RESULTS

The experimental data were subjected to statistical analysis to bring out the main effects of potassium, kinetin and their interactions on the growth, assimilate partitioning, nutrient uptake and yield of rice. The results obtained in the study are presented under the following sections.

1. Growth characters
2. Physiological characters
3. Nutrient uptake
4. Yield components and yield
5. Correlations
6. Economics

1. Growth characters

1.1. Plant height (Table 2)

Application of potassium increased plant height upto a level of 35 kg K_2O/ha.

Kinetin application increased the height of plants and the tallest plants were observed in plots treated with a single spray of kinetin at 10 DAF. The effect of this treatment was on par with that of 2 sprays of kinetin (at flowering and again at 10 DAF).

Table 2. Growth characters as influenced by Potassium and Kinetin.

Levels of K_2O (kg/ha)	Plant height (cm)			No.of tillers/m^2		Dry matter production (kg/ha)		
	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	30 DAT	60 DAT	Harvest
K_0	38.9	72.3	81.5	293	344	2707	4473	8049
$K_{17.5}$	43.8	80.6	82.7	340	425	3646	5410	9895
K_{35}	47.3	84.1	85.2	411	506	4058	6192	10652
K_{70}	47.4	82.4	84.4	437	528	4185	6388	11093
SEm±	0.73	0.82	0.45	4.16	7.74	64.2	70.2	220
CD (0.05)	2.12	2.38	1.31	12	22.4	185.5	203	635
Levels of Kinetin								
B_0: Water spray	-	-	82.3	-	-	-	-	8693
B_1: Kinetin (10 ppm) at F	-	-	82.8	-	-	-	-	9378
B_2: Kinetin (10 ppm) at 10 DAF	-	-	84.4	-	-	-	-	10532
B_3: Kinetin (10 ppm) at F+10 DAF	-	-	84.2	-	-	-	-	11087
SEm±	-	-	0.45	-	-	-	-	220
CD (0.05)	-	-	1.31	-	-	-	-	635

F = Flowering

DAF = Days after flowering

DAT = Days after transplanting

The interaction between potassium and kinetin did not influence the plant height.

1.2 Number of tillers per m^2 (Table 2)

Potassium application increased tiller production upto a level of 35 kg K_2O/ha.

1.3 Dry matter production (Table 2 and 4)

The effect of potassium on dry matter production (DMP) was significant at all the stages of the crop growth. The DMP did not increase beyond the level of 35 kg K_2O/ha.

Kinetin application also caused an improvement in dry matter production. A single spray of kinetin at 10 DAF and two sprays, first at flowering and second at 10 DAF, produced similar effects.

Interaction effect between potassium and kinetin on DMP was significant and 35 kg K_2O/ha along with a single spray of kinetin was found to be the optimum.

2. Physiological characters

2.1. Leaf area index (Table 3)

There was a progressive improvement in LAI due to successive levels of potassium upto the highest level tried (70 kg K_2O/ha).

2.2. Chlorophyll content (Table 3 and 4)

The total chlorophyll content of flag leaf at 15 DAF increased due to potassium application upto 35 kg K_2O/ha. At 25 DAF the effect of potassium on chlorophyll content was progressive only upto the level of 17.5kg K_2O/ha.

Two sprays of kinetin (at flowering and at 10 DAF) had the greatest effect on chlorophyll content compared to single sprays.

Potassium-kinetin interaction was marked on the chlorophyll content at 15 DAF. The highest values were noticed with plants supplied with 35 kg K_2O/ha plus two sprays of kinetin. However the effect of this treatment combination was on par with that of 35 kg K_2O/ha plus a single spray of kinetin.

2.3. Carbohydrate content (Table 3 and 4)

The leaf, sheath and culm contained more amounts of carbohydrates in plants which were not supplied with potassium. It was further noticed that the carbohydrate content of the source was decreasing with increase in the levels of potassium. The lowest values were noticed in plants supplied with the highest amount of applied K (70 kg K_2O/ha). On the contrary, a reverse trend was noticed in the carbohydrate content of panicle due to levels of potassium. The carbohydrate content of panicle was the highest when plants were supplied with 70 kg K_2O/ ha and its effect was on par with that of 35 kg K_2O/ha. In plants which

Table 3. LAI, Chlorophyll content, Carbohydrate content and Carbohydrate yield as influenced by Potassium and Kinetin.

Levels of K_2O (Kg/ha)	LAI at flowering.	Chlorophyll content of flag leaf (mg/g. fresh tissue)		Carbohydrate content at harvest (%)				Carbohydrate yield at harvest (kg/ha)				
		15 DAF	25 DAF	Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	Total
K_O	4.09	5.17	4.79	2.00	2.59	2.90	62.74	27.8	23.6	59.4	2325	2435
$K_{17.5}$	4.49	5.29	4.92	1.81	2.34	2.62	67.53	29.7	25.2	62.9	3229	3347
K_{35}	5.04	5.34	4.93	1.72	2.32	2.44	71.21	29.7	25.3	62.5	3699	3816
K_{70}	5.91	5.34	4.91	1.52	2.29	2.36	71.85	27.4	27.3	62.9	3891	4009
SEm±	0.025	-	-	-	-	-	-	-	-	-	-	-
CD (0.05)	0.071											
Levels of Kinetin												
B_0: Water spray	-	5.26	4.87	1.85	2.47	2.66	66.37	26.9	23.5	56.8	2747	2855
B_1: Kinetin (10 ppm) at F	-	5.28	4.88	1.78	2.39	2.59	67.56	27.1	23.2	58.9	3078	3188
B_2: Kinetin (10 ppm) at 10 DAF	-	5.28	4.89	1.72	2.35	2.55	68.72	29.9	26.9	65.2	3500	3622
B_3: Kinetin (10 ppm) at F+ 10 DAF	-	5.32	4.92	1.69	2.32	2.51	70.68	30.8	27.7	66.9	3818	3943
SEm±	-	0.007	0.005	0.01	0.01	0.02	0.49	0.717	0.829	1.57	75.9	78.3
CD (0.05)	-	0.019	0.014	0.03	0.03	0.06	1.43	2.07	2.39	4.52	219	226

Table 4. Potassium-Kinetin interactions on DMP at harvest, Chlorophyll content, Carbohydrate content and Carbohydrate yield.

Treatment combinations	DMP at harvest (kg/ha)	Chlorophyll content of flag leaf mg/g fresh tissue		Carbohydrate content at harvest (%)				Carbohydrate yield at harvest (kg/ha)				Total
		15 DAF	25DAF	Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	
K_0B_0	6828	5.16	4.78	2.09	2.87	3.05	60.02	24.1	21.8	51.8	1750	1848
K_0B_1	6817	5.17	4.78	2.08	2.64	2.92	60.23	25.1	20.7	51.4	1842	1940
K_0B_2	8947	5.13	4.79	1.94	2.47	2.83	64.40	30.7	25.6	65.7	2598	2720
K_0B_3	9905	5.23	4.84	1.88	2.38	2.80	66.30	31.4	26.1	68.9	3107	3234
K_1B_0	8858	5.21	4.88	1.91	2.34	2.71	65.97	29.3	23.5	61.3	2671	2786
K_1B_1	9154	5.27	4.91	1.84	2.35	2.60	65.77	27.8	23.3	57.7	2920	3029
K_1B_2	10057	5.33	4.94	1.75	2.37	2.61	66.87	28.9	25.7	63.3	3279	3396
K_1B_3	11510	5.34	4.94	1.75	2.30	2.53	71.50	32.6	28.3	69.6	4047	4177
K_2B_0	9344	5.31	4.90	1.81	2.34	2.52	68.80	27.8	23.6	56.9	3110	3218
K_2B_1	9973	5.36	4.92	1.72	2.32	2.52	71.27	27.4	20.3	61.1	3424	3533
K_2B_2	11398	5.33	4.94	1.68	2.30	2.38	72.00	31.4	28.2	65.2	4007	4131
K_2B_3	11895	5.36	4.96	1.66	2.29	2.35	72.77	32.0	29.2	66.8	4253	4381
K_3B_0	10041	5.34	4.90	1.60	2.33	2.36	70.7	26.2	25.0	57.1	3458	3567
K_3B_1	11569	5.33	4.91	1.49	2.29	2.35	72.97	28.1	28.4	65.4	4127	4249
K_3B_2	11725	5.33	4.92	1.51	2.26	2.37	71.60	28.8	28.4	66.5	4117	4241
K_3B_3	11039	5.34	4.93	1.47	2.28	2.34	72.13	26.7	27.2	62.6	3863	3979
SEm±	440	0.013	0.010	0.026	0.022	0.042	0.989	1.44	1.66	3.14	151.7	156.6
CD(0.05)	1270	0.038	NS	NS	0.064	NS	2.86	NS	NS	NS	438	452

were not supplied with potassium, the carbohydrate content of the panicle was the lowest.

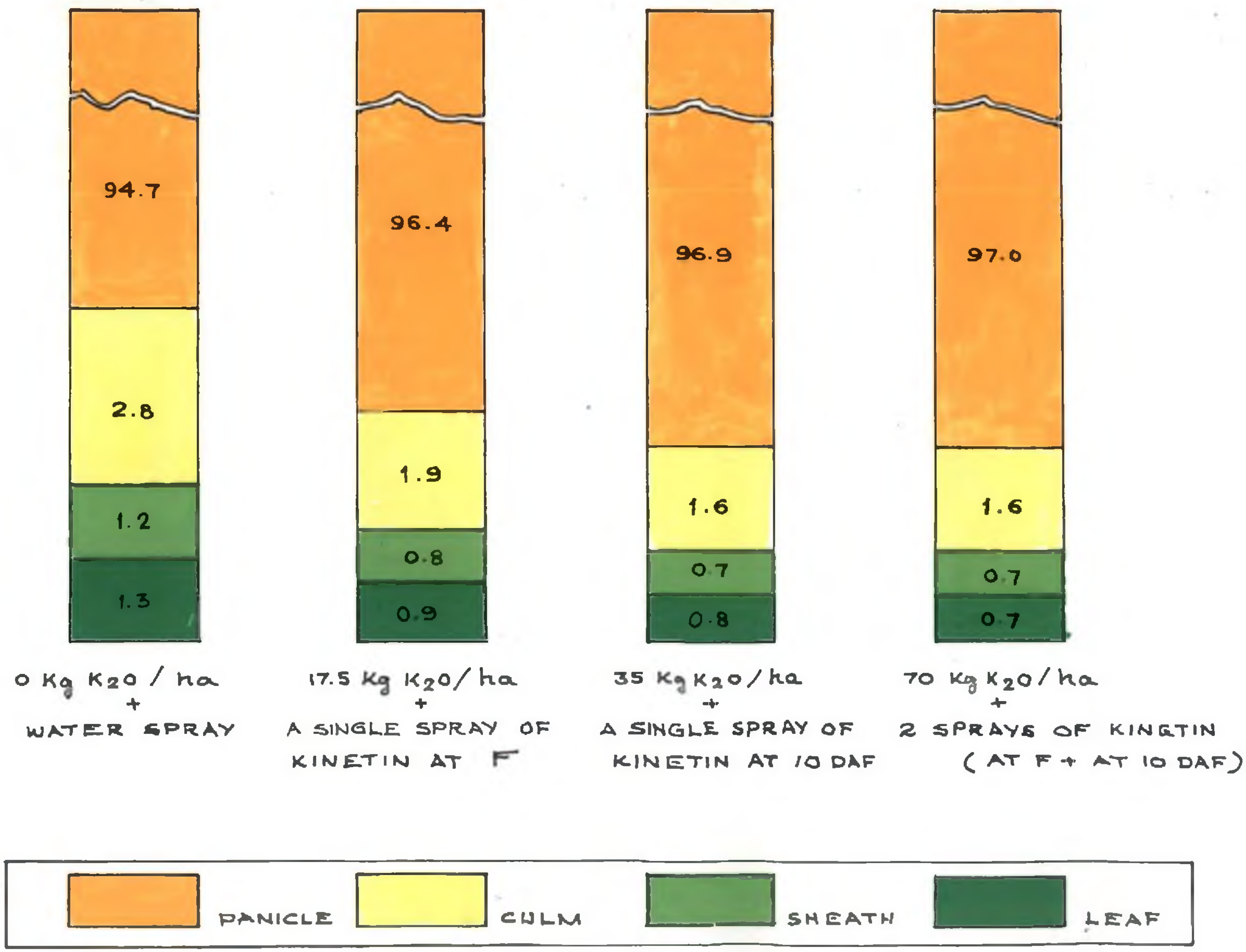
As in the case of potassium, kinetin application also influenced the carbohydrate content of different plant parts. The carbohydrate contents of the leaf, sheath and culm were highest in the control (water spray), while the plants treated with even a single spray of kinetin could decrease the carbohydrate content of the source. Correspondingly an improvement in the grain carbohydrate content was noticed due to kinetin application. A single spray of kinetin at 10 DAF caused considerable improvement on the grain carbohydrate content.

Interaction effect between potassium and kinetin was significant on the carbohydrate content of sheath and panicle. Plants supplied with neither potassium nor kinetin contained more percentage of carbohydrate in the source (leaf and sheath) while plants treated with higher doses of potassium (35 or 70 kg K_2O/ha) and one or two sprays of kinetin contained more amount of carbohydrate in the grains.. It was found that a dose of 35 kg potassium/ha along with a single spray of kinetin is optimum in this respect. Even application of potassium alone at 70 kg K_2O/ha had a similar effect on the grain carbohydrate content.

2.4. Carbohydrate yield (Table 3 and 4) & (Fig. 3)

Application of potassium did not influence the carbohydrate yield from the source while this nutrient had considerable influence

FIG. 3. CARBOHYDRATE YIELD (PERCENTAGE CONTRIBUTION) THROUGH DIFFERENT PLANT PARTS AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM



on the carbohydrate yield from the panicle as well as on the total carbohydrate yield from the plant. The carbohydrate yield from panicle and the total carbohydrate yield from the plant were found to be the highest with plants supplied with potassium @ 70 kg K_2O/ha and its effect was on par with that of 35 kg K_2O/ha.

Kinetin application influenced the carbohydrate yield from different plant parts as well as the total carbohydrate yield from the plant. A single spray of kinetin at 10 DAF resulted in higher amounts of carbohydrate yield through leaf, sheath and culm compared to a single spray at flowering or water spray. The carbohydrate yield from panicle as well as the total carbohydrate yield from the plant were highest with plants treated with 2 sprays of kinetin (at flowering and again at 10 DAF) compared to single sprays. Among the single sprays, kinetin spray at 10 DAF was better.

Potassium-kinetin interaction was significant only on the carbohydrate yield from the plant. It was found that a combination of 35 kg K_2O with single spray of kinetin at 10 DAF was optimum in this respect.

2.5. Protein content (Table 5 and 6)

As in the case of carbohydrate content the protein content of the source (leaf, sheath and culm) decreased with increase in the levels of applied potassium. The percentage content of protein in the source was highest in the plants which were not supplied with potassium. But a reverse trend was noticed on the protein content of sink due to levels of potassium. There was a progressive improvement in the protien content of panicle with successive levels of potassium upto the highest level tried (70 kg K_2O/ha).

The plants which were not treated with kinetin contained more amount of protein in the leaf and sheath and less in panicle compared to those treated with kinetin. The protein content of panicle increased due to kinetin spray. Two sprays resulted in highest percentage of protein in panicle followed by a single spray at 10 DAF.

Interaction between potassium and kinetin was found to be significant on the protein content of plant parts. Plants treated with neither potassium nor kinetin contained more amounts of protein in the source (leaf and sheath) and less in the sink compared to those applied with potassium and kinetin. The protein content of panicle was highest in plants treated with 35 kg K_2O/ha and 2 sprays of kinetin. The effect of this treatment combination was on par with that of 35 kg K_2O plus a single spray of kinetin (10 DAF).

2.6. Protein yield (Table 5 & 6) & (Fig. 4)

Potassium application increased the protein yield from the source (leaf sheath and culm) and the the sink. There was a progressive improvement in the protein yield from panicle as well as on the total protein

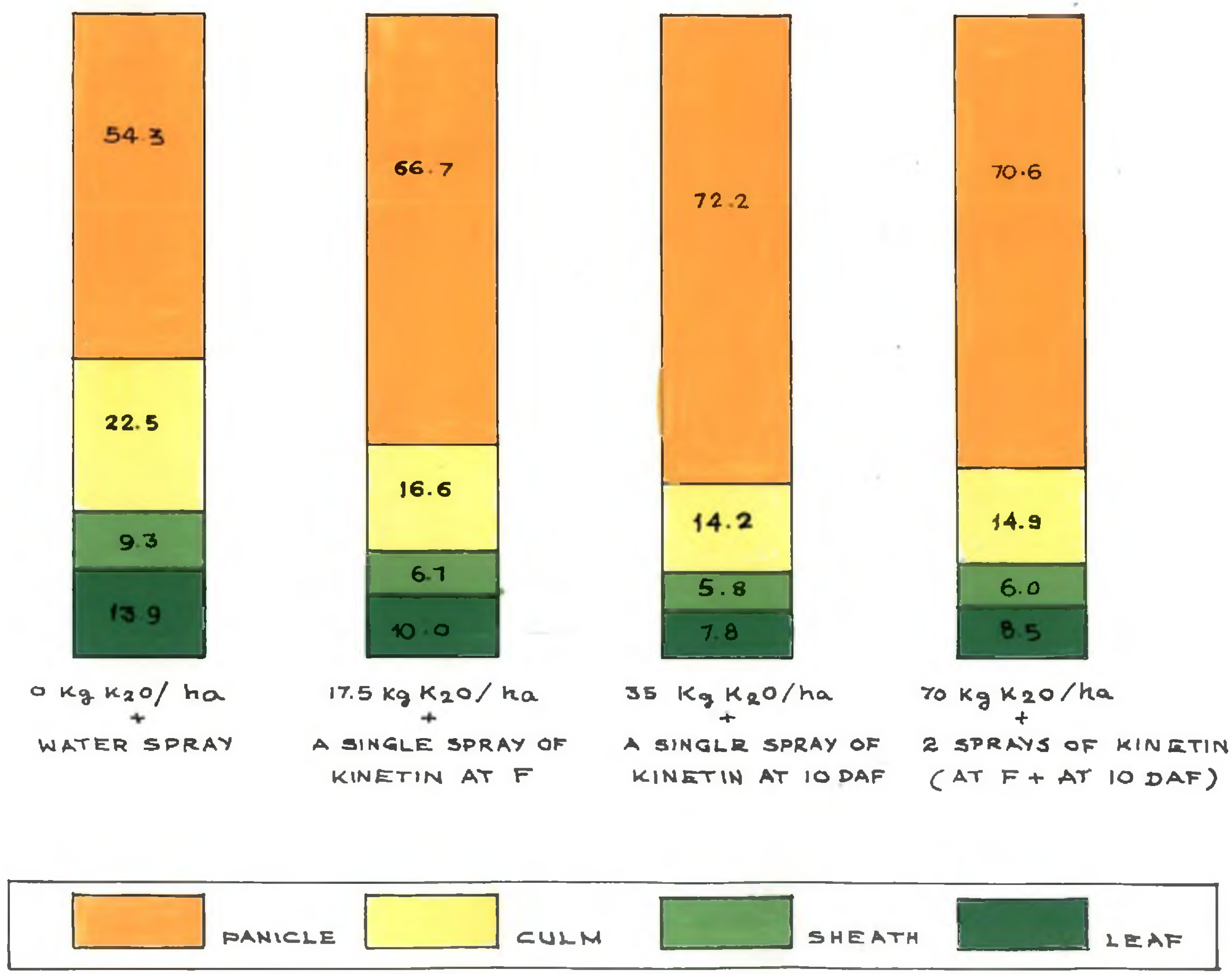
Table 5. Protein content, protein yield and nutrient uptake as influenced by Potassuim and Kinetin.

Levels of K_2O(kg/ha)	Protein content at harvest (%)				Protein yield at harvest (kg/ha)					Nutrient uptake at harvest (kg/ha)		
	Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	Total	N	P	K
K_0	3.62	3.73	4.06	6.65	50.7	34.2	83.5	250.6	418.9	95.3	26.4	93.8
$K_{17.5}$	3.47	3.60	4.01	8.40	56.9	38.8	96.7	405.5	596.0	113.2	32.5	113.5
K_{35}	3.22	3.53	3.95	8.96	56.1	40.4	92.8	469.7	667.5	138.1	35.2	135.3
K_{70}	3.23	3.54	3.91	9.55	58.6	42.2	104.5	517.8	723.0	140.8	35.6	147.2
Levels of Kinetin												
B_0: Water spray	3.49	3.64	3.97	7.52	50.9	34.9	85.4	318.1	489.2	106.6	29.0	103.4
B_1: Kinetin (10 ppm) at F	3.41	3.61	4.02	8.02	52.9	36.9	92.3	372.1	554.3	113.8	31.3	118.7
B_2: Kinetin (10 ppm) at 10DAF	3.33	3.59	3.99	8.65	57.9	41.3	102.6	445.9	647.8	128.6	34.9	130.5
B_3: Kinetin (10 ppm) at F+ 10 DAF	3.32	3.54	3.95	9.37	60.4	42.4	97.3	507.4	714.2	138.4	34.6	137.3
SEm±	0.036	0.014	0.039	0.083	1.35	0.89	4.63	9.6	13.6	1.83	0.50	0.89
CD(0.05)	0.105	0.041	NS	0.241	3.91	2.58	13.4	27.9	39.2	5.29	1.47	2.58

Table 6. Potassium-Kinetin interactions on protein content, protein yield and nutrient uptake

Treatment combinations	Protein content at harvest (%)				Protein yield at harvest (kg/ha)					Nutrient uptake at harvest (kg/ha)		
	Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	Total	N	P	K
K_0B_0	3.69	3.78	4.08	5.73	42.7	28.6	69.2	166.9	307.4	81.9	19.8	82.2
K_0B_1	3.55	3.78	4.07	6.07	42.2	29.9	71.8	186.3	330.7	85.5	22.8	86.5
K_0B_2	3.56	3.75	4.04	6.54	56.1	38.8	93.6	262.6	451.1	94.5	30.8	98.6
K_0B_3	3.66	3.59	4.05	8.26	61.2	39.3	99.3	386.5	586.3	119.4	32.1	108.0
K_1B_0	3.56	3.63	4.08	7.14	54.8	36.5	92.0	290.1	473.4	93.3	24.5	87.2
K_1B_1	3.59	3.68	4.04	8.13	54.1	36.5	89.8	360.1	540.5	91.5	32.4	96.2
K_1B_2	3.43	3.57	4.01	8.56	56.5	38.7	97.1	419.8	612.2	126.9	35.8	121.9
K_1B_3	3.31	3.53	3.92	9.76	62.0	43.3	107.9	552.1	757.9	141.0	37.2	148.7
K_2B_0	3.44	3.61	4.04	7.89	52.9	36.4	91.1	358.3	538.6	121.5	33.7	101.9
K_2B_1	3.34	3.49	4.03	8.12	55.2	37.9	97.8	390.1	581.0	132.7	33.3	144.5
K_2B_2	3.15	3.55	3.93	9.80	58.9	43.5	107.7	544.8	754.9	149.0	37.6	150.6
K_2B_3	2.96	3.45	3.80	10.02	57.3	43.8	74.7	585.4	795.6	149.2	36.4	144.2
K_3B_0	3.26	3.55	3.69	9.33	53.4	38.2	89.1	456.8	637.5	129.8	38.0	142.2
K_3B_1	3.16	3.48	3.95	9.76	59.7	43.3	109.7	552.1	764.8	145.4	36.5	147.5
K_3B_2	3.16	3.52	3.98	9.68	60.4	44.1	111.9	556.5	772.9	144.1	35.4	150.9
K_3B_3	3.35	3.61	4.01	9.44	60.9	43.1	107.2	505.7	716.9	143.9	32.7	148.3
SEm±	0.073	0.029	0.078	0.166	2.70	1.79	9.26	19.2	27.2	3.66	1.019	1.78
CD (0.05)	0.210	0.082	NS	0.482	NS	NS	NS	55.7	78.4	10.6	2.94	5.15

FIG. 4. PROTEIN YIELD (PERCENTAGE CONTRIBUTION) THROUGH DIFFERENT PLANT PARTS AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM



yield from the plant due to each successive levels of potassium upto the highest level tried (70 kg K_2O/ha).

Kinetin application resulted in high protein yield from the source and sink. Protein yield of panicle and the total protein yield from the plant were enhanced by kinetin application and the highest amounts were recorded in plants treated with 2 sprays of kinetin followed by a single spray at 10 DAF.

The interaction between kinetin and potassium was found to be significant on the protein yield from panicle and the total protein yield from the plant. Though the treatment combination 35 kg K_2O/ha plus 2 sprays of kinetin caused the production of highest amounts of protein (grain protein and total protein yield), the effect of this treatment combination was on par with that of 35 kg K_2O plus a single spray of kinetin at 10 DAF.

3. Uptake of Nitrogen, Phosphorus and Potassium (Table 5 and 6) & (Fig. 5, 6 & 7)

The uptake of N and P increased with increase in levels of potassium upto 35 kg K_2O/ha. But the K uptake increased progressively upto the highest level tried (70 kg K_2O/ha).

Kinetin application also increased the uptake of fertilizer nutrients (N, P and K). Two sprays of kinetin resulted in highest N and K uptake by the plants followed by a single spray at 10 DAF. In the case of phosphorus uptake, the effects of 2 sprays of kinetin and a single spray at 10 DAF were on par but superior to the single spray at flowering

FIG. 5. N UPTAKE AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM

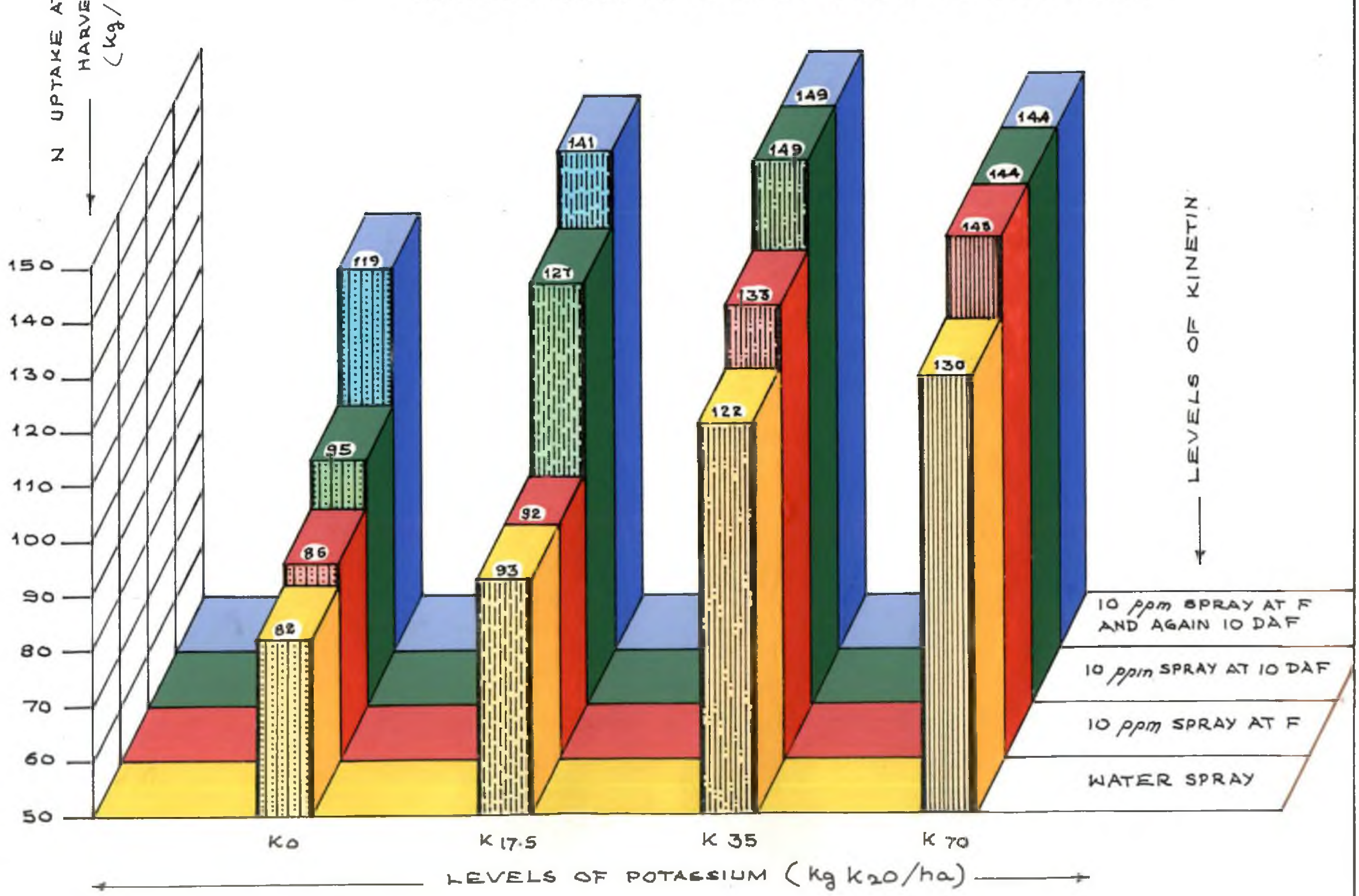


FIG. 6. P UPTAKE AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM

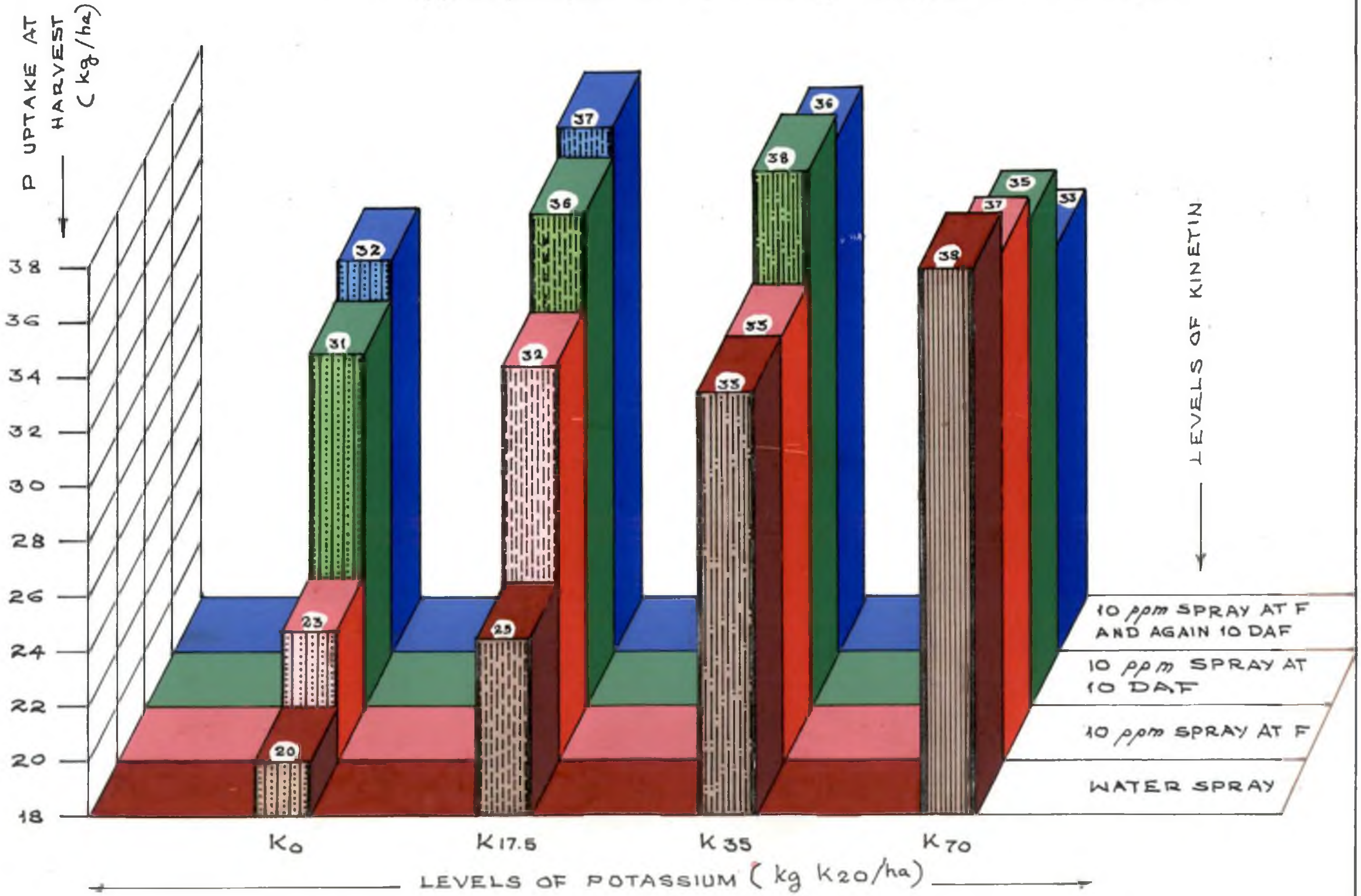
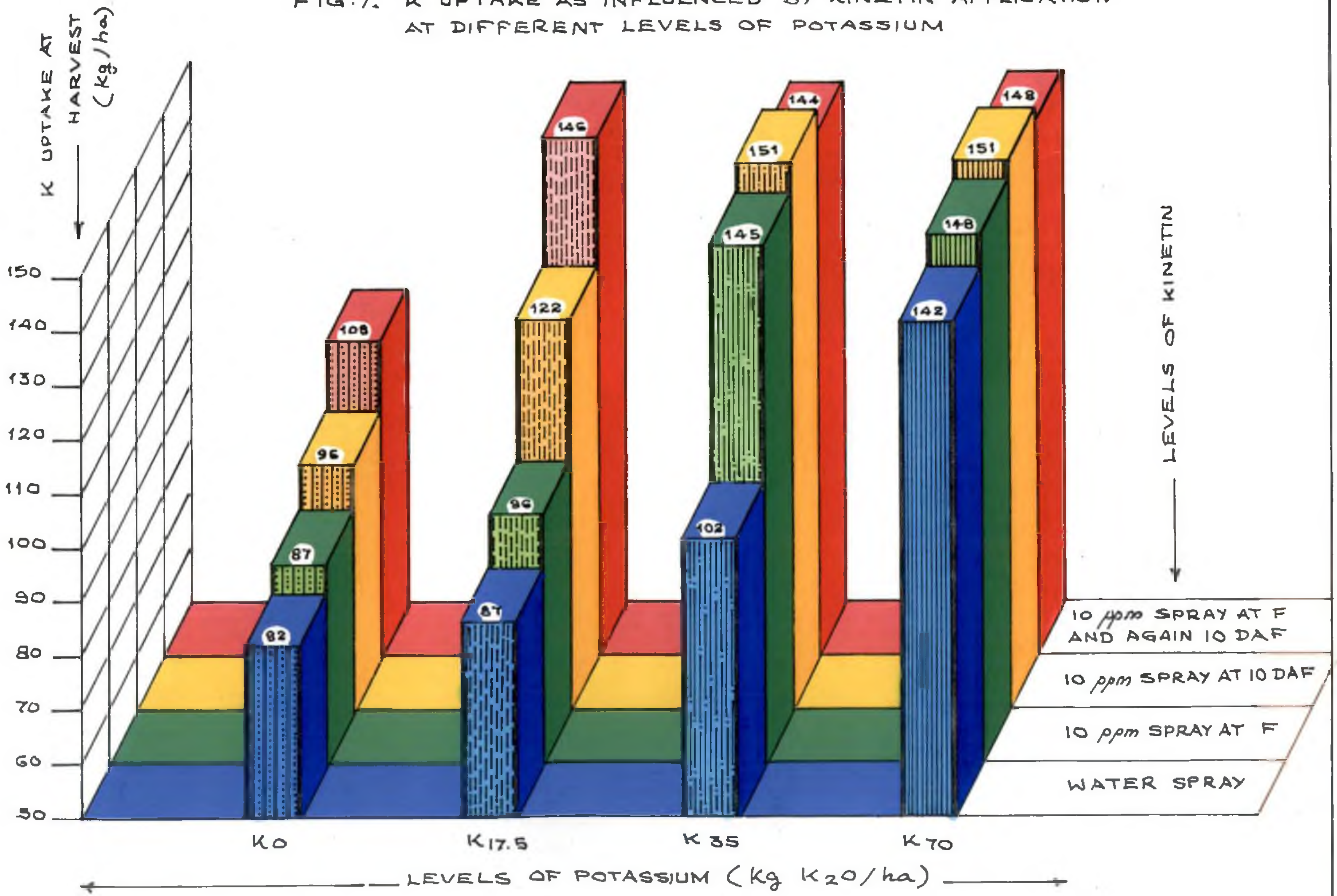


FIG.7. K UPTAKE AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM



and water spray.

Potassium-kinetin interactions influenced the uptake of major nutrients. Though the N uptake was highest in plants supplied with 35 kg K_2O and 2 sprays of kinetin, its effect was on par with that of 35 kg K_2O/ha with a single spray of kinetin (10 DAF). Phosphorus uptake was highest in plants treated with 70 kg K_2O/ha without kinetin and the effect of this treatment was similar to that of 35 kg K_2O/ha plus a single spray of kinetin at (10 DAF). Potassium uptake was highest with plants treated with 70 kg K_2O/ha and 2 sprays of kinetin and the effect of this treatment was similar to that of 35 kg K_2O/ha with a single spray of kinetin (10, DAF).

4. Yield attributes and yield

4.1. Number of panicles per m^2 (Table 7 and 8)

Number of panicles per m^2 increased progressively with increase in the levels of potassium upto the highest level tried (70 kg K_2O/ha).

Kinetin appliction increased the panicle number per m^2, 2 sprays of kinetin producing highest number of panicles followed by a single spray at 10 DAF.

Interaction effect between potassium and kinetin was significant on number of panicles/m^2, 70 kg K_2/ha with 2 sprays of kinetin producing the highest number. The effect of this treatment was on par with that of 70 kg K_2O/ha with single spray (10 DAF).

4.2. Panicle length (Table 7 and 8)

Panicle length increased due to potassium application and the effect was not considerable beyond 17.5 kg K_2O/ha.

Neither the direct effect of kinetin nor the interaction effect between potassium and kinetin could alter the panicle length.

4.3. Number of spikelets perpanicle (Table 7 and 8)

Potassium application increased the spikelet number per panicle upto 70 kg K_2O/ha.

Kinetin application also proved to be effective and single spray of kinetin at flowering was found to be sufficient in this respect.

Spikelet number per panicle was highest in plants supplied with 70 kg K_2O/ha plus a single spray of kinetin at flowering.

4.4. Number of filled grains per panicle (Table 7 and 8)

Number of filled grains per panicle increased with increase in levels of potassium upto the highest dose tried (70 kg K_2O/ha).

Kinetin application had beneficial effect on the number of filled grains per panicle. Two sprays of kinetin resulted in the production of highest number of filled grains per panicle followed by a single spray at 10 DAF.

Table 7. Yield attributes, yield, harvest index and economics of rice production as influenced by Potassium and Kinetin.

Levels of K_2O(kg/ha)	No. of panicles/m^2	Panicle length (cm)	No. of spikelets/panicle	No. of filled grains/panicle	Filled grain percentage	1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index	Economics of rice production: Net Income (Rs/ha)	Economics of rice production: Net return per rupee invested (Rs.)
K_0	274	19.4	90.5	60.1	66.3	22.7	3670	4379	0.46	4430	0.86
$K_{17.5}$	356	21.1	94.0	70.6	75.1	24.1	4761	5135	0.48	6951	1.35
K_{35}	380	21.5	97.8	78.6	80.4	25.8	5185	5464	0.49	7926	1.53
K_{70}	422	21.5	109.1	91.5	83.9	26.7	5416	5677	0.49	8421	1.61
Levels of Kinetin											
B_0:Water Spray	340	20.5	94.5	71.0	74.8	24.2	4098	4591	0.47	5927	1.30
B_1:Kinetin (10ppm) at F	343	20.4	98.2	74.2	75.1	24.7	4489	4889	0.48	6257	1.21
B_2:Kinetin (10ppm) at 10DAF	367	21.2	99.0	77.1	77.4	25.0	5058	5473	0.48	7684	1.49
B_3:Kinetin (10ppm) at F+10 DAF	382	21.5	99.7	78.4	78.4	25.4	5386	5701	0.49	7857	1.36
SEm±	2.41	0.24	0.44	0.40	0.39	0.07	103	120	0.002	264	0.05
CD(0.05)	6.97	0.71	1.29	1.16	1.13	0.21	298	346	0.006	762	0.15

Note:- 1. Cost of K_2O - Rs.2.16/kg
2. Cost of Kinetin - Rs.200/g
3. Value of paddy - Rs.2/- kg
4. Value of straw - Rs.0.50/kg

Table.8 Potassium-Kinetin interactions on yield attributes, yield, harvest index and economics of rice production.

Treatment combination	No. of panicles m^2	Panicle length (cm)	No. of spikelets/ panicle	No. of filled grains	Filled grains percentage	1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index	Economics of rice production	
										Net income (Rs/ha)	Net return per rupee invested
K_0B_0	229	18.3	87.1	55.8	64.0	22.4	2914	3614	0.45	3135	0.70
K_0B_1	237	18.6	90.0	58.7	65.2	22.7	3062	3754	0.45	2902	0.57
K_0B_2	311	19.9	91.7	60.8	66.3	22.7	4019	4927	0.45	5402	1.06
K_0B_3	320	20.7	93.1	64.9	69.7	23.2	4686	5219	0.47	6282	1.10
K_1B_0	347	21.7	93.4	69.9	74.9	23.4	4053	4805	0.46	5971	1.32
K_1B_1	355	21.1	93.7	69.9	74.6	23.8	4431	4723	0.48	6085	1.18
K_1B_2	354	21.0	94.6	71.5	75.6	24.1	4902	5155	0.49	7244	1.41
K_1B_3	368	20.8	94.4	71.1	75.3	24.9	5656	5854	0.49	8501	1.48
K_2B_0	369	20.7	96.1	74.3	77.3	24.8	4525	4806	0.49	6877	1.50
K_2B_1	368	21.3	96.8	76.0	78.6	25.6	4808	5165	0.48	7022	1.36
K_2B_2	374	22.0	97.6	80.0	81.9	26.1	5562	5833	0.49	8865	1.71
K_2B_3	409	22.1	100.6	84.0	83.8	26.7	5845	6050	0.49	8939	1.55
K_3B_0	415	21.3	101.4	83.9	82.8	26.1	4902	5139	0.49	7723	1.66
K_3B_1	412	20.6	112.4	92.3	82.1	26.8	5656	5913	0.49	9018	1.72
K_3B_2	429	21.9	112.1	96.1	85.8	27.0	5750	5974	0.49	9237	1.76
K_3B_3	432	22.4	110.6	93.6	84.7	27.0	5357	5681	0.49	7705	1.32
SEm±	4.83	0.592	0.894	0.802	0.784	0.148	206	240	0.004	528	0.106
CD(0.05)	13.9	NS	2.58	2.32	2.26	0.430	596	NS	0.012	1523	0.306

Potassium-kinetin interaction was significant on the number of filled grains per panicle and the highest values were noted in plots treated with 70 kg K_2O/ha plus a single spray of kinetin at 10 DAF.

4.5. Percentage of filled grains (Table 7 and 8)

As in the case of number of filled grains per panicle, the percentage of filled grains also increased due to patassium application upto the level of 70 kg K_2O/ha.

Kinetin application also increased the percentage of filled grains and a single spray at 10 DAF was found to be the best.

The interaction effect between potassium and kinetin was also significant and application of potassium at 70 kg K_2O/ha with a single spray of kinetin at 10 DAF resulted in the highest percentage of filled grains.

4.6. Thousand grain weight (Table 7 and 8)

Thousand grain weight increased with increase in levels of potassium upto the highest level tried (70 kg K_2O/ha).

Kinetin application also caused considerble improvement in the test weight of grains, two sprays of kinetin resulted in highest test weight followed by a single spray at 10 DAF.

The interaction effect between potassium and kinetin was significant and the plants treated with potassium @ 70 kg K_2O/ha plus a single spray of kinetin at 10 DAF produced bolder grains.

4.7. Grain yield (Table 7 and 8) & (Fig. 8)

Grain yield increased due to potassium application upto a level of 70 kg K_2O/ha and the effect at this level was on par with that of 35 kg K_2O/ha.

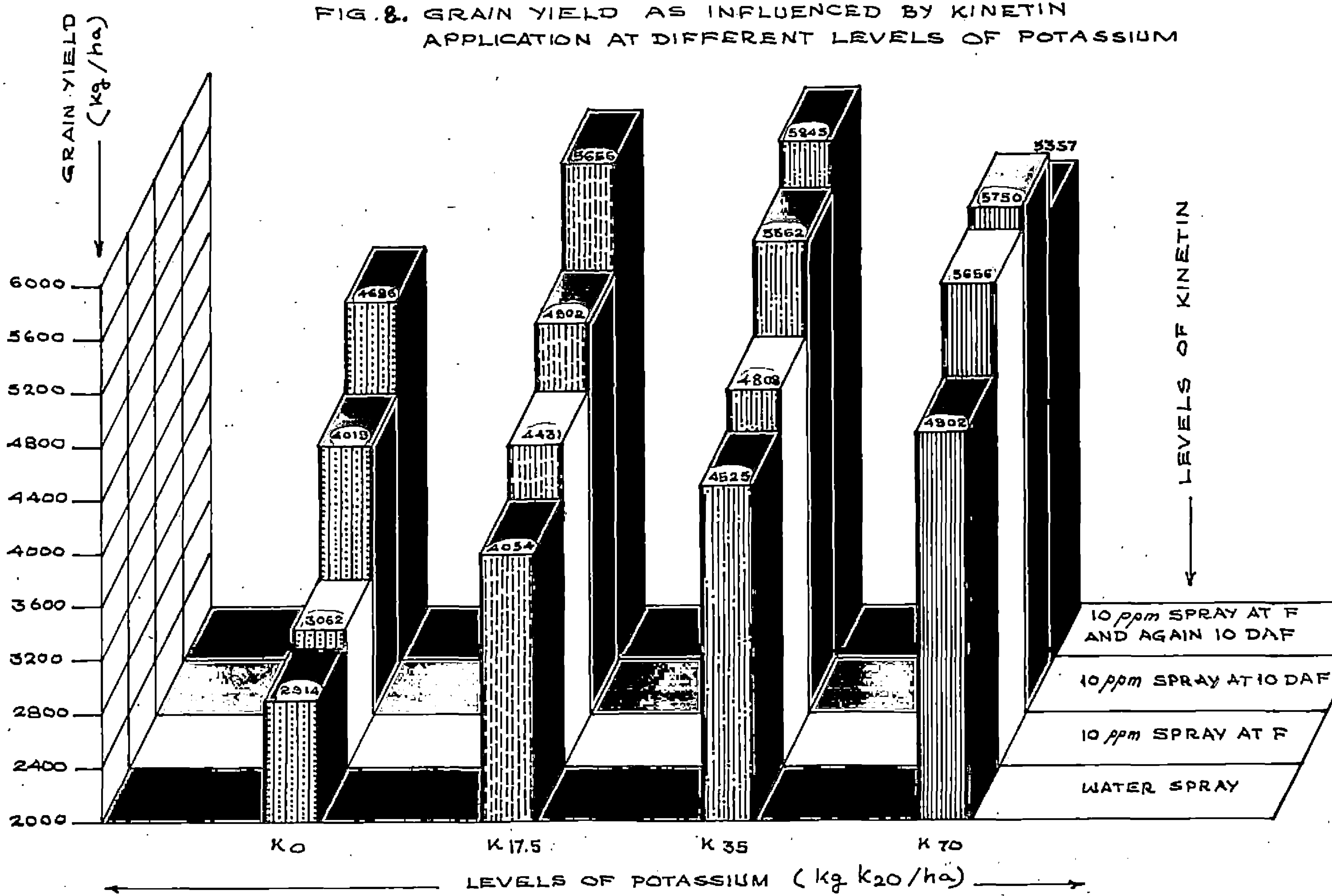
Kinetin application increased the grain yield significantly and two sprays of kinetin resulted in the production of highest amounts of grain followed by a single spray at 10 DAF and then by a single spray at flowering.

The potassium-kinetin interaction was synergestic on grain yield and the treatment combination 35kg K_2O/ha plus two sprays of kinetin caused the production of the highest amounts of grains. The effect noticed with this treatment combination was on par with that of 35 kg K_2O plus a single spray of kinetin at 10 DAF.

4.8. Straw yield (Table 7 and 8)

Potassium application increased straw yield upto a level of 35 kg K_2O/ha.

FIG. 8. GRAIN YIELD AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM



Kinetin application also caused significant improvement in straw yield and a single spray of kinetin at 10 DAF was optimum.

4.9. Harvest index (Table 7 and 8) & (Fig.9)

Harvest index increased due to potassium application. The highest values of harvest index were noticed with plants supplied with potassium @ 35 K_2O/ha and the effect at this level was on par with that of 70 kg K_2O/ha.

Significant improvement in harvest index was noticed due to kinetin application and two sprays of kinetin resulted in highest harvest index compared to single sprays and water spray. The effects of single sprays (at flowering or 10 DAF) were similar but superior to water spray.

The interaction effect also altered the harvest index. Application of 17.5 kg K_2O/ha plus a single spray of kinetin resulted in the highest harvest index (0.49).

5. Correlation (Table 9) & (Fig. 10 & 11)

The grain yield, straw yield, harvest index, carbohydrate yield from panicle, protein yield from panicle and potassium uptake by plants exhibited a significant positive correlation with all the parameters presented in Table 9 except with carbohydrate and protein contents of leaf, sheath and culm with which a significant negative correlation existed.

FIG. 9. HARVEST INDEX AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM

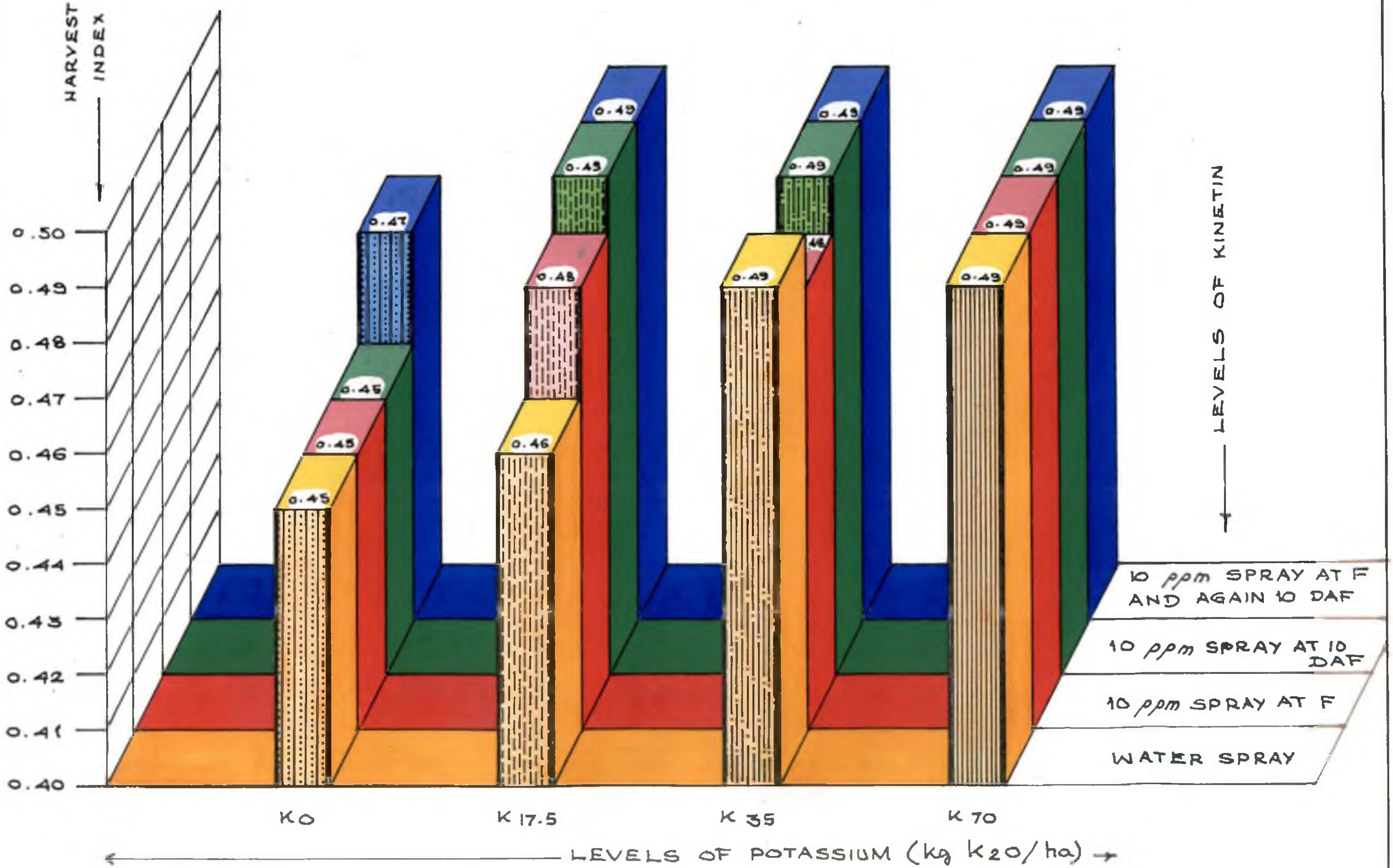


TABLE - 9. CORRELATION STUDIES IN RICE

Sl. No:	Growth Characters		Grain yield	Straw yield	Harvest index	Carbohy-drate yield from panicle	Protein yield from panicle	K uptake at harvest
1	2		3	4	5	6	7	8
	A							
1	Plant height	- 30 DAT	0.68	0.58	0.69	0.71	0.71	0.70
2		- 60 DAT	0.75	0.65	0.78	0.76	0.75	0.69
3		- Harvest	0.68	0.66	0.56	0.69	0.66	0.61
4	No.of Tillers/m^2	- 30 DAT	0.74	0.66	0.74	0.79	0.78	0.84
5		- 60 DAT	0.78	0.70	0.75	0.82	0.82	0.84
6	Dry matter production	- 30 DAT	0.89	0.82	0.81	0.90	0.90	0.83
7		- 60 DAT	0.84	0.73	0.88	0.86	0.87	0.83
8		- Harvest	0.99	0.99	0.71	..	..	..
	B.Physiological characters							
1	Leaf area index		0.69	0.61	0.64	0.73	0.75	0.80
2	Chlorophyll content	- 15 DAF	0.77	0.62	0.89	0.79	0.82	0.82
3		- 25 DAF	0.75	0.69	0.82	0.80	0.82	0.74
4	Carbohydrate content	- Leaf	- 0.81	- 0.74	- 0.75	- 0.84	- 0.85	- 0.87
5		- Sheath	- 0.80	- 0.76	- 0.73	- 0.80	- 0.78	- 0.67
6		- Culm	- 0.83	- 0.73	- 0.82	- 0.86	- 0.86	- 0.84
7		- Panicle	0.87	0.83	0.71	0.92	0.87	0.87
8	Carbohydrate yield	- Leaf	0.60	0.72	0.16	0.56	0.49	0.35
9		- Sheath	0.71	0.78	0.31	0.70	0.69	0.51
10		- Culm	0.73	0.85	0.26	0.69	0.62	0.45
11		- Panicle	0.99	0.96	0.78	..	0.98	0.88
12	Total carbohydrate yield		0.99	0.96	0.77	0.99	0.98	0.88
13	Protein content	- Leaf	- 0.72	- 0.65	- 0.63	-0.74	- 0.77	- 0.74
14		- Sheath	- 0.81	- 0.75	- 0.71	-0.83	- 0.82	- 0.77
15		- Culm	- 0.39	- 0.34	- 0.39	-0.40	- 0.43	- 0.41
16		- Panicle	0.91	0.81	0.84	0.92	0.97	0.89
17	Protein yield	- Leaf	0.82	0.90	0.42	0.79	0.72	0.56
18		- Sheath	0.94	0.99	0.55	0.92	0.87	0.73
19		- Culm	0.56	0.59	0.33	0.55	0.50	0.49
20		- Panicle	0.98	0.91	0.81	0.98	..	0.89
21	Total protein yield		0.99	0.95	0.78	0.99	0.99	0.88
	C.Nutrient uptake							
1	N uptake at harvest		0.85	0.77	0.77	0.88	0.90	0.92
2	P uptake		0.83	0.76	0.78	0.83	0.83	0.79
3	K uptake		0.85	0.78	0.75	0.88	0.89	..
	D.Yield attributes & yield							
1	No. of panicles/m^2		0.83	0.76	0.78	0.85	0.85	0.80
2	Panicle length		0.63	0.59	0.56	0.63	0.63	0.58
3	No. of spikelets/panicle		0.69	0.65	0.58	0.72	0.73	0.73
4	No. of filled grains/panicle		0.79	0.72	0.70	0.82	0.82	0.81
5	Percentage of filled grains		0.82	0.74	0.77	0.85	0.85	0.82
6	1000 grain weight		0.81	0.72	0.79	0.85	0.86	0.90
7	Grain yield		..	0.97	0.79	0.99	0.98	0.85
8	Straw yield		0.97	..	0.61	0.96	0.91	0.78
9	Harvest index		0.79	0.61	..	0.78	0.81	0.75

FIG. 10: CORRELATION BETWEEN GRAIN YIELD AND CARBOHYDRATE CONTENT OF PLANT PARTS.

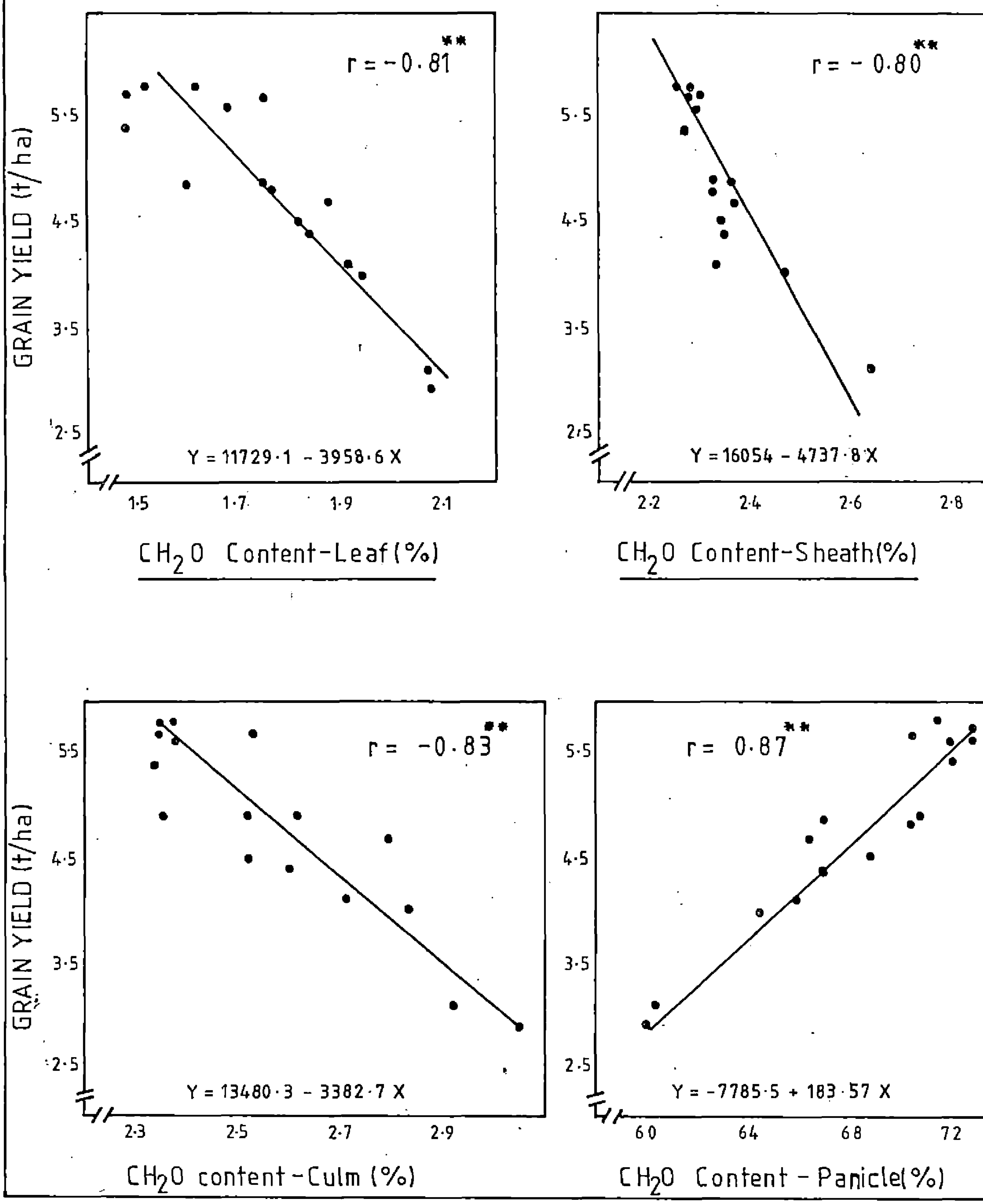
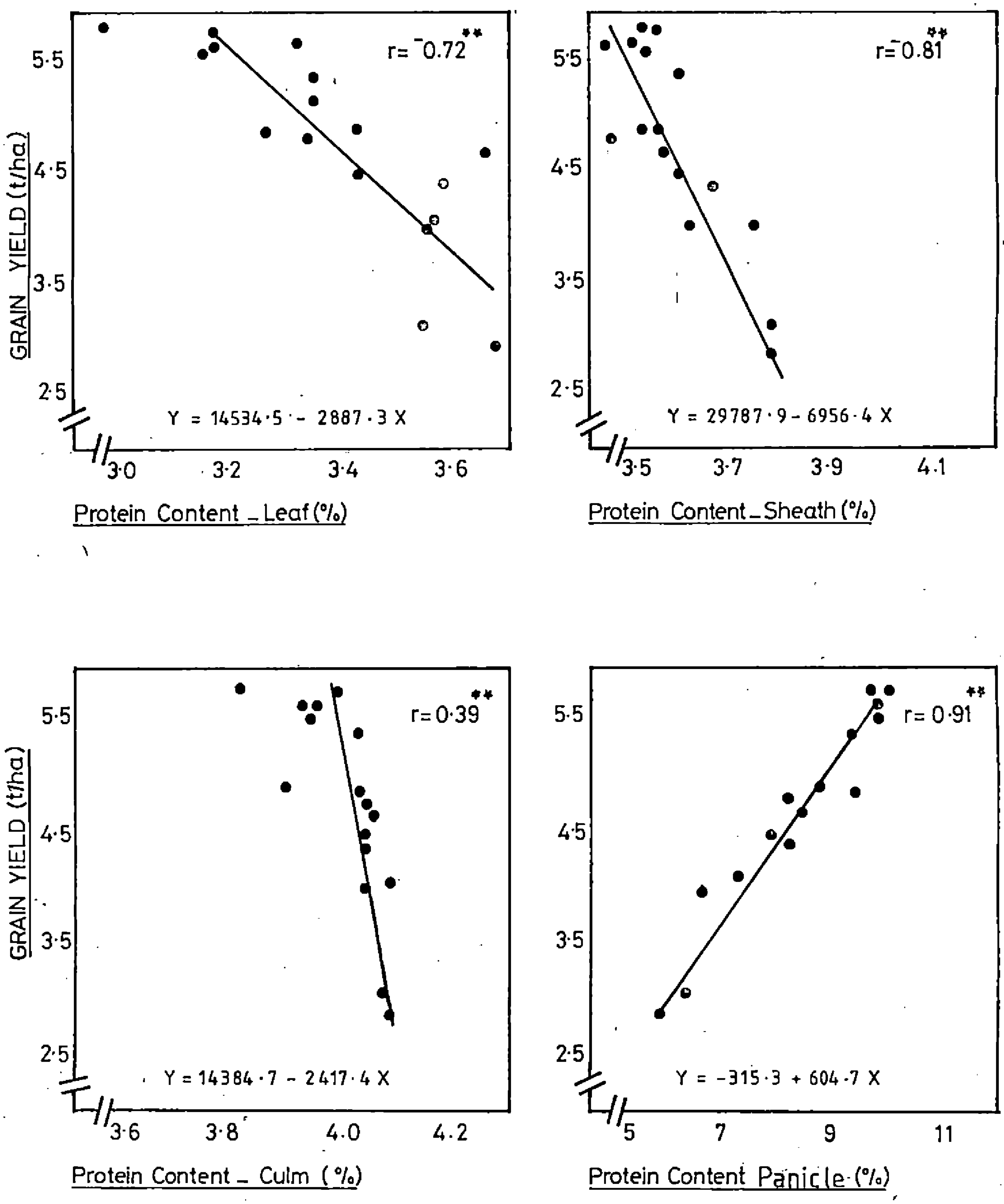


Fig. 11. CORRELATION BETWEEN GRAIN YIELD AND PROTEIN CONTENT OF PLANT PARTS



6. Economics

6.1. Net income (Table 7 and 8) & (Fig.12)

Potassium application increased the net income upto a level of 35 kg K_2O/ha.

Kinetin application also increased the net income from rice. Though the highest net income was noticed when two sprays of kinetin were given, its effect was on par with that of a single spray at 10 DAF.

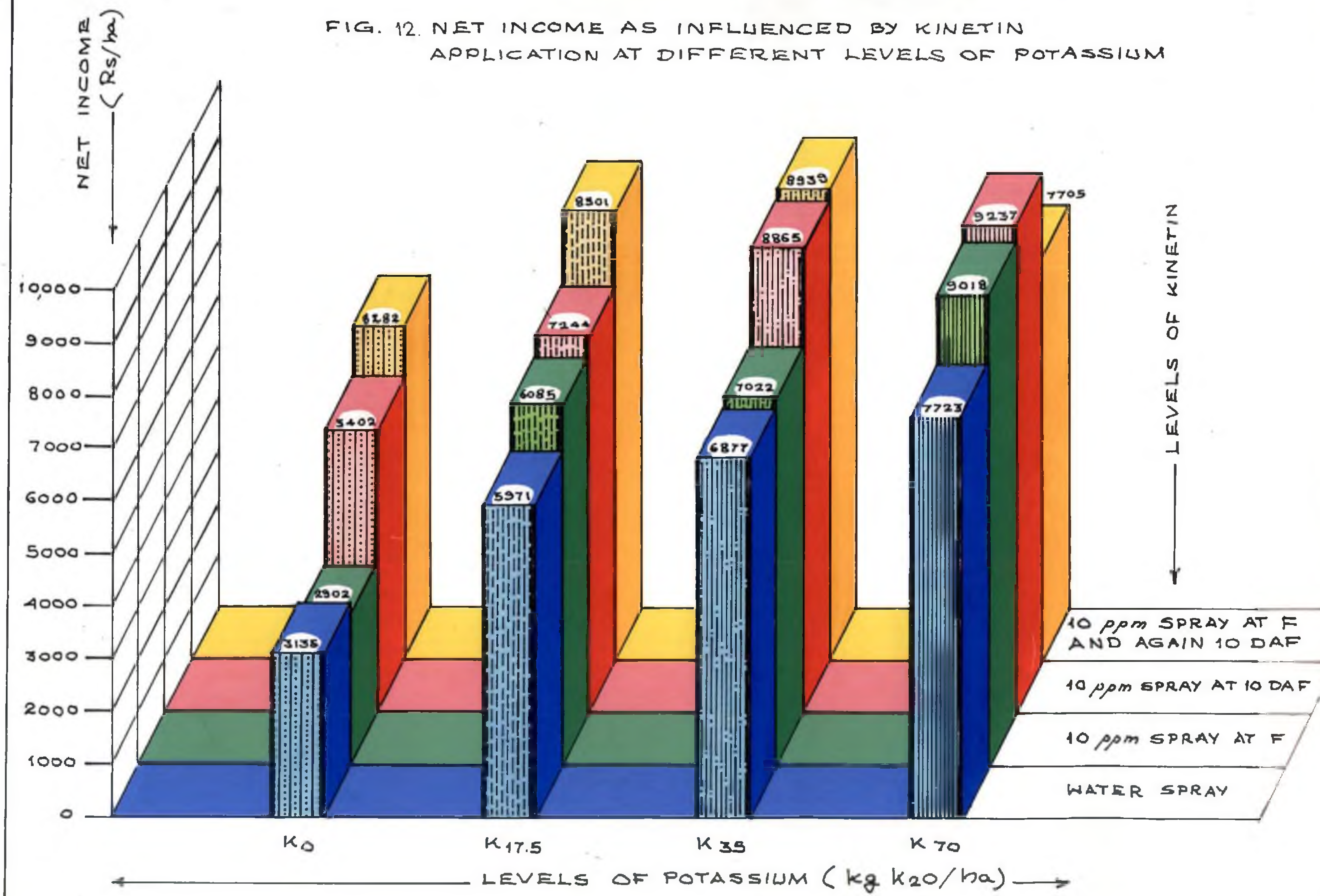
The highest net income was obtained with the treatment combination 70 Kg K_2O/ha plus a single spray of kinetin at 10 DAF. But the net income obtained due to this treatment combination was on par with that of 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF.

6.2. Net return per rupee invested (Table 7 and 8)

As in the case of net income, the net return per rupee invested was also increased due to potassium, kinetin as well as their interactions. The net return per rupee invested increased upto a level of 70 kg K_2O/ha. A single spray of kinetin at 10 DAF resulted in highest net return per rupee invested

Among the treatment combinations, the net return per rupee invested was highest with 70 kg K_2O/ha plus a single spray of kinetin at 10 DAF. But the effect at this level was on par with that of 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF.

FIG. 12. NET INCOME AS INFLUENCED BY KINETIN APPLICATION AT DIFFERENT LEVELS OF POTASSIUM



DISCUSSION

5. DISCUSSION

A field experiment was conducted at the Cropping Systems Research Centre, Karamana, Trivandrum during summer 1987 to study the effect of potassium and kinetin on the growth, assimilate partitioning nutrient uptake and yield of a short duration rice variety Triveni in the lowlands. The results of the experiment are discussed in this chapter.

1. Growth characters

Growth characters such as plant height, tiller production and DMP increased considerably due to potassium application (Table 2). The effect was positive only upto a level of 35 kg K_2O/ha. Potassium nutrition helps the development of a healthy root system (Noguchi and Sugawara, 1966) and improves the absorption of essential meneral nutrients and thus the plant growth. Influence of potassium in promoting photosynthesis has been reported by many workers (Smid and Peaslee, 1976; and Mengel and Kirkby, 1983). As potassium is vital for the activity of many enzymes involved in photosynthesis, an adequate supply of this element to the plants enhances the rate of photosynthesis. Research has shown that green leaves with high potassium content are able to assimilate twice as much CO_2 as leaves with lower potassium contents (Smid and Peaslee, 1976). Increase in plant height (Vijayan and Sreedharan, 1972; Venkata Subbaiah et al. 1982; and Xu et al. 1984), tiller production (Kulkarni et al. 1975; Singh and Singh, 1979; and Linbao, 1985) and dry matter production (Hoang, 1974; Mishra, 1980; Hati and Misra, 1983; and Senthivel and Palaniappan, 1985) due to potassium application has been reported earlier.

A single spray of kinetin at 10 DAF could cause significant improvement in plant height and total DMP. The DMP increased by 21 per cent due to kinetin spray compared to water spray. This indicates that kinetin application promoted photosynthesis. Yoshida (1972) reported similar effects of kinetin on DMP in rice. Biswas and Choudhuri (1977) found that application of 100 ppm kinetin at post flowering stage was very effective in retarding the rate of respiration and increasing the DMP in the rice variety Jaya.

The interaction effect between potassium and kinetin was synergestic on total DMP. The combined effects of 35 kg K_2O/ha either with a single spray of kinetin at 10 DAF (11398 kg DMP/ha) or with 2 sprays of kinetin (11895 kg DMP/ha) were similar and the DMP was 78 to 82 per cent more compared to control.

2. Physiological characters

2.1. Leaf area index

Potassium application increased LAI progressively upto the highest level tried (70 kg K_2O/ha). The highest LAI (5.91) was noticed with plants treated with potassium at the rate of 70 kg K_2O/ha registering a 44 per cent increase over control. In this study it was also found that potassium application had a similar effect on tiller production as well. The enhanced tiller production due to potassium application might be responsible for the observed trend in LAI. Hoang (1974) and Mandal and Dasmahapatra (1983) observed similar effects of potassium on LAI in rice.

2.2. Chlorophyll content

Data on chlorophyll content at 15 DAF as well as on 25 DAF clearly indicate that potassium nutrition can increase the longivity of flag leaf and a dose of 35 kg K_2O/ha is optimum in this respect. Application of potassium beyond this level did not increase the longivity of flag leaf further. The results obtained in the present study corroborate with the findings of many workers (Hoang, 1974; Ray and Choudhuri, 1980; and Das and Sarkar, 1981). The delayed senescence due to potassium application results in prolonged leaf area duration (Ralph, 1976; and Forster, 1976) which is important for an effective sink (Evans et al. 1975).

Kinetin spray caused significant improvement in the chlorophyll content of flag leaf (Table 3). It was found that 2 sprays of kinetin (first at flowering and second at 10 DAF) resulted in the production of highest amount of chlorophyll. The effects of single sprays at flowering and at 10 DAF were similar in this respect. Kinetin application increases the chlorophyll content apparently, by maintaining the nucleic acid content (Herzog, 1981). Debata and Murty (1981) reported that foliar spray of 10 ppm kinetin delayed senescence by increasing the chlorophyll content. This was further confirmed by Ray et al. (1983)

Potassium-kinetin interaction was found to be positive on the chlorophyll content of flag leaf at 15 DAF. The highest chlorophyll content (5.36 mg/g fresh tissue) was noticed in the plants treated with 35 kg K_2O/ha and a single spray of kinetin at flowering. Increasing the number of sprays of kinetin did not cause improvement in the flag leaf longivity. In other words application of 35 kg K_2O/ha along with a single spray of kinetin (at flowering or 10 DAF) was sufficient in this respect.

2.3. Carbohydrate content and Carbohydrate yield

Potassium application influenced not only the carbohydrate content in different plant parts but also the carbohydrate yield from them (Table 3). The carbohydrate content of the leaf, sheath and culm decreased with increase in the levels of potassium upto 35 kg K_2O/ha and after which the effect was not marked. Correspondingly carbohydrate yield from panicle increased with increase in the levels of potassium upto 35 kg K_2O/ha. Application of potassium beyond this level did not cause significant improvement in carbohydrate yield. The leaf carbohydrate content decreased from 2 per cent to 1.52 per cent between plants supplied with zero and 70 kg K_2O/ha (Table 3). The carbohydrate content of sheath decreased from 2.59 to 2.29 per cent while that of culm decreased from 2.90 to 2.36 per cent between these treatments. On the contrary carbohydrate contents of panicle increased from 62.74 to 71.85 per cent between the plants treated with zero and 70 kg K_2O/ha.

The carbohydrate yield from panicle increased from 2325 kg/ha to 3699 kg/ha between plants treated with zero and 35 kg K_2O/ha registering a 59 per cent increase. The total carbohydrate yield from the plant increased by 57 per cent between these treatments. Potassium application beyond 35 kg K_2O/ha did not cause significant improvement on the carbohydrate yield either from the panicle or from the plant as a whole and it appears that a dose of 35 kg K_2O/ha is optimum in this respect.

The favourable effects of potassium in promoting photosynthesis (Smid and Peaslee, 1976) and translocation of assimilates (Mengel and Haeder, 1977; Mengel and Kirkby, 1983) are well documented. Increased potassium supply might have accelerated CO_2 uptake by the plants as well as the translocation of carbohydrates to the ear (Haeder and Mengel, 1974). The flow of assimilates in the phloem vessels is reported to be faster when plants are well supplied with potassium (Mengel and Haeder, 1977). Hartt (1979) using $^{14}CO_2$ established that in sugarcane, translocation of assimilates from the leaves to stalk was faster in plants well supplied with potassium. Haeder et al. (1973) confirmed this role of potassium in potatoes using labelled CO_2. They further reported that rapid transport of assimilates to the storage organs is important not simply because more assimilates are stored thereby increasing the yield but also because of evacuation of assimilates from the leaves enabling photosynthesis to continue. The positive effect of potassium on the synthesis and transport of carbohydrates from the vegetative parts to the panicle has been reported by many workers (Mishra, 1980; Roy et al. 1980; Mengel and Kirkby, 1983; and Vil' Gel' M, 1986). The results obtained in the present study are in conformity with the findings of the above.

The carbohydrate content of source (leaf, sheath and culm) decreased due to kinetin spray with corresponding increase in the grain carbohydrate content. Two sprays of kinetin resulted in the highest percentage of grain carbohydrate (70.7 per cent). The carbohydrate yield also increased considerably due to kinetin spray. Plants treated with 2 sprays of kinetin (first at flowering and second at 10 DAF) produced highest amounts of carbohydrate from panicle (3818 kg/ha) and total carbohydrate from plants (3943 kg/ha) both registering a 38 per cent increase over water spray. The results indicate that kinetin application causes more or less similar effect as that of potassium application with regard to assimilate transport.

Kinetin application decreased the carbohydrate content of leaf from 1.85 per cent (water spray) to 1.69 per cent (2 sprays of kinetin). The carbohydrate content of sheath decreased from 2.47 per cent to 2.32 per cent and that of clum from 2.66 per cent 2.51 per cent between plants treated with water spray and 2 sprays of kinetin. Correspondingly carbohydrate content of panicle increased from 66.4 per cent to 70.7 per cent between plants treated with water spray and 2 sprays of kinetin. The data thus reveal that kinetin application can decrease the carbohydrate content of the source with a corresponding increase in the carbohydrate content of the sink, indicating the favourable influence of this bioregulant on assimilate transport. Mothes and Engelbrecht (1961) and Krishnamoorthy (1981) reported that kinetin influences the direction of transport of organic metabolites and minerals and their accumulation in the sink.

The potassium-kinetin interaction was significant on the carbohydrate content (sheath and panicle) as well as the carbohydrate yield (from panicle and total carbohydrate yield from plant). It can be seen from the Fig.3 that the plants supplied with neither potassium nor kinetin held 5.30 per cent of the total carbohydrate in the source while those supplied with potassium and kinetin (35 or 70 kg K_2O/ha along with one or two sprays of kinetin) retained only less (3.00 to 3.10 per cent) in the straw. Correspondingly there was an improvement in the grain carbohydrate content.

Application of 35 kg K_2O/ha along with a single spray of kinetin at 10 DAF resulted in the highest percentage of accumulation of carbohydrates in the grain (96.90 per cent). The potassium-kinetin interaction was synergestic on the carbohydrate yield from panicle as well as the total carbohydrate yield from the plant. A dose of 35 kg K_2O/ha along with a single spray of kinetin at 10 DAF was found to be optimum in this respect. Compared to water spray, the carbohydrate yield from the panicle and the total carbohydrate yield from the plant with this treatment combination were more by 129 per cent and 124 per cent respectively.

2.4. Protein content and protein yield

Potassium application altered the protein accumulation in different plant parts as well as the total protein yield from them (Table 5). The protein content of source (leaf, sheath and culm) decreased with increase in the levels of potassium upto 35 kg K_2O/ha and after which the effect was not marked. Protein yield from panicle as well as the total protein yield from the plant increased with increase in levels of potassium upto the highest level tried (70 kg K_2O/ha).

The leaf protein content decreased from 3.62 per cent to 3.22 per cent between plants supplied with zero and 35 kg K_2O/ha while the sheath protein content decreased from 7.73 to 3.53 per cent between them (Table 5). Correspondingly the protein content of panicle increased with incremental dose of potassium.

The protein yield from panicle increased by 106 per cent in plants treated with 70 kg K_2O/ha compared to control while the total protein yield from plant increased by 73 per cent between these treatments. Insufficient supply of potassium to the plants results in an increase in the protein accumultion in the vegetative parts (Hsiao et al. 1970; Mengel and Koch, 1971).

The protein content of source (leaf, sheath and culm) decreased due to kinetin spray with the corresponding increase in the grain protein content. Two sprays of kinetin resulted in the accumulation of highest amounts of protein in the grains (9.37 per cent). Higher nitrogen uptake was noticed due to kinetin treatment (Table 5) which might have helped the plant to produce more proteins. The protein yield also increased considerably due to kinetin spray. Plants treated with 2 sprays of kinetin produced highest amount of panicle protein (507 kg/ha) as well as the total protein from plants (714 kg/ha). Compared to water spray, the plants treated with 2 sprays of kinetin produced 59 per cent more of panicle protein and 46 per cent more of total protein. Kinetin spray decreased the protein content of leaf from 3.49 to 3.32 per cent and of sheath from 3.64 to 3.54 per cent between the treatments, water spray and 2 sprays of kinetin. Correspondingly the protein content of panicle increased from 7.52 per cent to 9.37 per cent. The results reveal that kinetin application decreases the protein content of the source and increases the protein content of the sink thus indicating a favourable effect of this hormone on assimilate partitioning to the economic sink.

The beneficial effects of kinetin on the translocation of proteins from the vegetative parts to the grain have been reported by several workers (Lovell, 1971; Wagner, 1974 and Simpson et al. 1982).

The potassium-kinetin interaction was significant on the protein content of leaf, sheath and panicle and synergestic on the protein yield (panicle protein and total protein yield) of rice. Application of 35 kg K_2O/ha along with a single spray of kinetin at 10 DAF was found to be optimum in this respect (Fig.4). The plants supplied with neither potassium nor kinetin held 45.70 per cent of the total protein in the source and 54.30 per cent in the sink while those supplied with potassium @ 35 kg K_2O/ha and a single spray of kinetin at 10 DAF retained only 27.80 per cent in the source and as much as 72 per cent of the proteins were translocated to the sink.

3. Uptake of nitrogen, phosphorus and potassium

The uptake of N and P increased in levels of potassium upto 35 kg K_2O/ha and after which the effect was not progressive. The potassium uptake increased with increase in levels of potassium upto the highest level tried (70 kg K_2O/ha). Potassium application increased the N uptake from 95 to 138 kg/ha between the plants supplied with zero and 35 kg K_2O/ha registering a 45 per cent increase. Phosphorus uptake between these treatments increased from 26 to 35 kg/ha registering a 33 per cent increase. The potassium uptake increased from 93 to 147 kg/ha between plants treated with zero and 70 kg K_2O/ha registering a 57 per cent increase.

The total DMP also increased due to potassium application (Table 2) and thus the nutrient absorption as well. The increased uptake of N, P and K due to higher levels of potassium has been reported by many workers (Mengel et al. 1976; Steineck and Haeder, 1980 and Singh and Singh, 1987).

Kinetin application also increased the uptake of fertilizer nutrients (N, P and K). Two sprays of kinetin resulted in the highest N and K uptake by rice registering 30-33 per cent increase compared to water spray. Even a single spray of kinetin at 10 DAF was effective than water spray in this respect. In the case of phosphorus uptake, the effects of 2 sprays of kinetin and a single spray at 10 DAf were on par and superior to water spray. Perhaps the effect of kinetin on DMP (Table 5) might be responsible for the observed trend on nutrient uptake. Enhanced N uptake due to kinetin application was reported by Yoshida and Oritani, 1979 and Simpson et al. 1982.

Potassium-kinetin interactions were synergestic on the uptake of major nutrients. The treatment combination 35 kg K_2O/ha and a single spray of kinetin at 10 DAF was found to be the best with regard to the uptake of nitrogen, phosphorus and potassium. The nitrogen, phosphorus and potassium uptake increased by 82, 89 and 83 per cent respectively between the treatments control and "35 kg K_2O/ha plus a single spray of kinetin at 10 DAF".

4. Yield components

The yield components such as number of panicles per m^2, panicle length, number of spikelets per panicle, number of filled grains per panicle, percentage of filled grains and thousand grain weight increased progressively with increase in the levels of potassium upto the highest level tried (70 kg K_2O/ha). The number of panicles per m^2 were 274 and 422 for the treatments zero and 70 kg K_2O/ha respectively. Panicle length increased from 19.4 to 21.5 (11 per cent), number of spikelets per panicle from 90.5 to 109.1 (21 per cent), number of filled grains per panicle from 60.1 to 91.5 (52 per cent), filled grain percentage from 66.3 to 83.9 (27 per cent) and thousand grain weight from 22.7 to 26.7 (18 per cent) between the treatments zero and 70 kg K_2O/ha. Matsushima _et al._ (1968) reported that the increase in the number of spikelets per panicle is at the expense of stored carbohydrate in sheath and culm of rice. Improvement in the apparent contribution rate of carbohydrate from source to sink (Fig.3) might be responsible for an increase in thousand grain weight. Potassium nutrition favoured translocation of assimilates from source to sink resulting in an increase in test weight and number of grains per ear (Beringer, 1985). Favourable influences of potassium on number of panicles per m^2, panicle length, spikelet number per panicle, percentage of filled grains and test weight have been reported by several workers (Uexkull, 1976; Varma _et al._ 1979; Mandal and Dasmahapatra, 1983; Venkatasubbiah _et al._ 1982; Xu _et al._ 1984; Linbao, 1985)

Two sprays of kinetin resulted in highest number of panicles per m^2 (382), panicle length (212.5 cm), number of spikelets per panicle (99.7), number of filled grains per panicle (78.4), filled grain percentage (78.4) and thousand grain weight (25.4). Among the single sprays, kinetin spray at 10 DAF was the best compared to that at flowering to improve the yield components in rice. Cytokinins possess the property of directed transport of metabolites from source to sink (Mothes and Engelbrecht, 1961) and increase the number and size of individual sinks (Holmes, 1974). Michael and Beringer (1980) reported that cytokinins may affect yield formation through the promotion of cell division and the build up of storage capacity. Presumably in the later stage, their main function is retardation of senescence and thus keeping the leaves green and active for a longer period.

The beneficial effect of kinetin on number of panicles per m^2, panicle length, number of spikelets per panicle, number of filled grains per panicle, filled grain percentage and thousand grain weight has been reported by several workers (Biswas and Choudhuri, 1977; Ray and Choudhuri, 1981; Debata and Murty, 1981; Santokh and Gurbaksh, 1982; and Gurbaksh et al. 1984).

The main effect of potassium on yield components such as number of panicles per m^2, number of spikelets per panicle, number of filled grains per panicle, percentage of filled grains and thousand grain weight were modified by kinetin spray. In general the highest values with regard to these yield components were noticed with plants treated with 70 kg K_2O/ha and a single spray of kinetin at 10 DAF. The percentage increase in number of panicles per m^2, number of spikelets per panicle, number of filled grains per panicle, percentage of filled grains and thousand grain weight with treatment "35 kg K_2O/ha plus a single spray of kinetin at 10 DAF" were respectively 63, 12, 43, 28 and 17 per cent more compared to control.

5. Grain yield

Grain yield increased due to potassium application upto a level of 35 kg K_2O/ha and after which the effect was not progressive. The grain yield increased from 3670 kg to 5185 kg between the plants treated with zero and 35 kg K_2O/ha registering a 41 per cent increase. The data on growth characters and yield components presented in table 2 and 7 revealed that potassium nutrition enhanced the growth and improved the yield attributes and in general the effects were significant upto a level of 35 kg K_2O/ha. Potassium application also enhanced the uptake of nitrogen, phosphorus and potassium (Table 5). This might have caused more functional leaf area and chlorophyll content (Table 3) in potassium treated plants resulting in greater photosynthesis. Consequently the plants could provide a better source to the sink. Beneficial effects of potassium on photosynthesis (Smid and Peaslee, 1976), flag leaf longivity (Hoang, 1974; Ray and Choudhuri, 1980; and Das and Sarkar, 1981), phloem loading and phloem transport (Haeder and Mengel, 1974; ~~1977~~, Hartt, 1979; and Mengel and Kirkby, 1983) were reported by many workers. Potassium application thus cause not only the production of assimilates but also hastens the translocation of assimilates to the sink.

Many researchers have reported the positive influence of potassium on grain yield in rice (Sahu and Ray, 1976; Halm and Dartey, 1977; Robinson and Rajagopalan, 1977; Singh and Prakash, 1979; Agarwal, 1980; Mahapatra et al. 1980 and Gurmani et al. 1984). The dose of potassium that is being recommended by the Kerala Agricultural University for short duration rice in sandy loam soils of Kerala is 35 kg K_2O/ha (Anon, 1986). From the results it appears that the main effect of potassium beyond 35 kg K_2O/ha may not be beneficial in the test area.

Kinetin application caused a pronounced effect on grain yield. Two sprays of kinetin resulted in the production of the highest amounts of grain (5386 kg/ha) followed by a single spray at 10 DAF (5058 kg/ha) and then by a single spray at flowering (4489 kg/ha). The grain yield due to 2 sprays of kinetin, a single spray at 10 DAF and a single spray at flowering were more by 31, 23 and 10 per cent respectively over water spray. Kinetin application increased the chlorophyll content of flag leaf (Table 3) and delayed the flag leaf senescence. This might have increased the photosynthesis during the ripening phase. The improvement in grain number, grain weight and grain fillage (Table 7) in kinetin treated plants might be the reflection of the beneficial effects of this bioregulant on the post flowering photosynthesis.

Kinetin also played a vital role on the partitioning of carbohydrates and protein (Table 3 and 5) between the source and the sink. The increased grain yield noticed due to kinetin application might have been channelised through the beneficial effect of this bioregulant on photosynthsis, assimilate transport, grain fillage and grain weight. The study gives definite indications on the positive influence of kinetin on grain yield in rice. Two sprays of kinetin resulted in the production of the highest amounts of grain. But from the economic point of view it was found that a single spray of kinetin at 10 DAF was optinum (Table 7). Similar effects of kinetin on grain yield of rice were reported by Biswas and Choudhuri, 1977; Ray and Choudhuri, 1981; and Debata and Murty, 1981.

The potassium-kinetin interaction was synergestic on grain yield and application of 35 kg K_2O/ha plus 2 sprays of kinetin resulted in the production of the highest amounts of grain (5845 kg/ha) and its effect was on par with that of 35 kg K_2O/ha with a single spray of kinetin at 10 DAF (5562 kg/ha). The grain yield increased by 101 per cent between the plants treated with neither potassium nor kinetin and those treated with 35 kg K_2O/ha plus 2 sprays of kinetin. The yield increase with the treatment 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF over absolute control was in the order of 91 percentage.

It may be noted that the main effect of potassium was restricted to a level of 35 kg K_2O/ha. Regarding kinetin application, it was found that 2 sprays of kinetin resulted in the production of highest amount of grain followed by a single spay at 10 DAF. It can be seen from Table 8 that the combined effect of potassim and kinetin was more than additive and the effect was found to be synergestic. The results indicate that the main effect of potassium can be modified favourably with kinetin spray during the post flowering stage to enhance the grain yield. The data on the carbohydrate and protein content of plant parts presented in Table 3 to 6 suggests that this favourable effect was channelised through the effects of potassium and kinetin to translocate the synthates to the sink which other wise would have accumulated in the source. It appears that both the main effects as well as the interaction effects of potassium and kinetin was positive to increase the photosynthesis and to mobilise the synthates from the source to the sink.

Data on correlation presented in Table 9 showed that there existed a strong negative correlation between grain yield and carbohydrate content of leaf, sheath and culm. The correlation between grain yield and leaf carbohydrate content was -0.81 while that between grain yield and sheath carbohydrate content was -0.80. The correlation between grainyield and carbohydrate content of culm was - 0.83. But there was strong positive correlation between grain yield and carbohydrate content of the panicle (0.87). The results indicate that application of potassium and kinetin decreased the carbohydrate content of the source and increased the carbohydrate content of the panicle. Consequently the grain yield of rice was also increased.

From the results obtained the following conclusions can be drawn.

1. The effects of potassium and kinetin are synergestic on growth, yield and nutrient uptake of rice and a combination of 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF is optimum.

2. Both potassium as well as kinetin application prevent the accumulation of carbohydrate and protein in the source and enhanced their accumulation in the sink. Their interaction effect is also favourable in this respect and 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF is optimum.

6. Straw yield

Potassium application increased straw yield upto a level of 35 kg K_2 O/ha. The straw yield increased from 4379 kg to 5464 kg registering a 25 per cent increase between the treatments zero and 35 kg K_2O/ha. The beneficial effects of potassium observed on growth characters (Table 2) explain this. The positive influence of potassium in increasing straw yield in rice has been reported by many workers (Singh et al. 1976; Singh and Prakash, 1979; and Venkatassubbiah et al. 1982).

Kinetin application also caused an improvement in straw yield and a single spray of kinetin at 10 DAF was found to be optimum in this respect. The straw yield increased from 4591 kg to 5473 kg/ha, between the treatments water spray and kinetin spray at 10 DAF, registering a 19 per cent increase.

7. Harvest index

Harvest index increased due to potassium application upto a level of 35 kg K_2O/ha and after which the effect was not progressive. The harvest index increased from 0.46 to 0.49 between the treatments zero and 35 kg K_2O/ha. The harvest index is a measure of the amount of dry matter accumulated in the sink in relation to the total biomass produced by the plant (Snyder and Carlson, 1984). The results obtained in the present study indicate the positive influence of potassium on the assimilate partitioning to the economic sink. The favourable effect of potassium on translocation of photosynthates has been reported by many researchers (Hartt, 1970; 1979; Haeder et al. 1973; Mengel and Viro, 1974; Mengel and Krikby, 1983).

Kinetin application increased the harvest index and 2 sprays of kinetin resulted in the highest harvest index (0.49). The effects of single sprays on harvest index were on par with 2 sprays, but it was higher than water spray. Kinetin treatment might have augmented the photosynthatic activity of the leaves resulting in higher production and mobilization of photosynthates to the grains. The result obtained in the present study is in agreement with the findings of Biswas and Choudhuri, 1977; and Ray et al. 1983.

The effect of potassium on harvest index was different when kinetin treatment was combined. It can be seen from Table 8 and Fig. 9 that the effects of kinetin with potassium doses of 17.5 kg and 35.0 kg K_2O/ha were similar but higher than that of control (0 kg K_2O/ha). A single spray of kinetin at flowering 17.5 kg K_2O/ha as well as 35.0 kg K_2O/ha resulted in a harvest index of 0.48 while a single spray of kinetin at 10 DAF with potassium doses of 17.5 kg as well as 35.0 kg K_2O/ha resulted in the same harvest index (0.49). The results indicate that a higher harvest index can be achieved even with a lower dose of potassium if kinetin spray can be combined. The same effect can be obtained even by applying potassium alone at higher doses (70 kg K_2O/ha). The favourable effect of potassium as well as kinetin on assimilate synthesis as well as translocation (from the source to the sink) already discussed in the earlier sections explain the observed trend in harvest index.

8. Correlations

The correlations of grain yield, straw yield, harvest index, carbohydrate yield from panicle, protein yield from panicle and potassium uptake at harvest with different plant characters presented in Table 9 and Fig. 10 and 11 bring out certain interesting results. It was found that the grain yield, straw yield, harvest index, carbohydrate yield from panicle, protein yield from panicle and potassium uptake by crop at harvest exhibit significant positive correlation with many plant characters except with few physiological characters (carbohydrate and protein content of leaf, sheath and culm). It was also found that there existed a significant negative correlation between the carbohydrate and protein contents of leaf, sheath and culm with grain yield. The relationships of straw yield, harvest index, carbohydrate yield from panicle, protein yield from panicle as well as potassium uptake with the carbohydrate and protein content of leaf, sheath and culm was also negative.

The result indicate that a decrease in the carbohydrate and protein contents of leaf, sheath and culm will increase the potassium uptake, carbohydrate yield from panicle, protein yield from panicle, grain yield, straw yield and harvest index of rice. The results further suggest that any agronomic attempt to decrease the carbohydrate and protein contents of leaf, sheath and culm of rice would result in an improvement in the grain and straw yields of rice. In the present study it was found that application of potassium and kinetin caused a significant reduction in the carbohydrate and protein content of leaf, sheath and culm. Correspondingly there was an increase in the grain yield of rice.

9. Economics

9.1. Net return and net return per rupee invested

Potassium application upto 35 kg K_2O/ha increased the net return as well as the net return per rupee invested. Between potassium levels of zero and 17.5 kg K_2O/ha. the increase in net income was in the order of Rs.3496/- and Rs.975/- indicating a higher profitability at lower doses of potassium application. The marginal returns went on decreasing with increase in the levels of potassium application.

Kinetin application increased the net return and net return per rupee invested. It was found that a single spray of kinetin at at 10 DAF was optimum giving a net return of Rs.7684/- and net return per rupee invested of Rs.1.49. The net return obtained with a single spray of kinetin at 10 DAF was Rs.1757/- more than that of water spray. The results clearly indicate the beneficial effect of kinetin to increase the net returns from rice.

The net return as well as the net return per rupee invested due to potassium application were different with and without kinetin application. Application of 35 kg K_2O/ha with a single spray of kinetin at 10 DAF gave a net return of Rs.8865/- and net return per rupee invested of 1.71. The net return due to the treatment combination 35 kg K_2O/ha plus a single spray kinetin at 10 DAF was Rs.5730 higher than that obtained with control.

From the results obtained from the study it can be concluded that application of 35 kg K_2O/ha along with a single spray of kinetin at 10 DAF is an efficient and economic combination of potassium and kinetin for rice during summer.

SUMMARY

6. SUMMARY

A field experiment was conducted at the Cropping Systems Research Centre, Karamana, Trivandrum during summer 1987 to study the effect of potassium and kinetin on the growth, assimilate partitioning, nutrient uptake and yield of a short duration rice variety Triveni. The soil of the experimental field was sandy loam, acidic in reaction, low in available nitrogen and potassium and medium in available phosphorus. The weather was normal during the period of crop growth. The treatments involved a factorial combination of 4 levels of potassium (0, 17.5, 35.0 and 70.0 kg K_2O/ha) and 4 levels of kinetin (water spray, 10 ppm kinetin at flowering, 10 ppm kinetin at 10 DAF and 10 ppm kinetin at flowering and again at 10 DAF). The experiment was laid out in a randomised block design with three replications. The results of the experiment are summarised below.

1. Plant height, tiller production and DMP of rice increased due to potassium application upto a level of 35 kg K_2O/ha. A single spray of kinetin at 10 DAF caused considerable inprovement in plant height and total DMP. The interaction between potassium and kinetin was synergestic on total DMP at harvest and a combination of 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF was optimum.

2. Potassium application increased LAI upto a level of 70 kg K_2O/ha.

3. Potassium-kinetin interaction was positive on the chlorophyll content of flag leaf and the highest chlorophyll content was noticed with plants treated with 35 kg K_2O/ha plus a single spray of kinetin at flowering.

4. The potassium-kinetin interaction was significant on the carbohydrate content of plant parts. Plants supplied with neither potassium nor kinetin contained more amounts of carbohydrate in the 'source' while those supplied with potassium and kinetin (35 or 70 kg K_2O/ha along with one or two sprays of kinetin) showed higher accumulation of carbohydrates in the 'sink'.

5. The potassium-kinetin interaction was synergestic on the carbohydrate yield from panicle as well as on the total carbohydrate yield from plant. A dose of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF was optimum in this respect.

6. The potassium-kinetin interaction was significant on the protein content of plant parts and application of 35 kg K_2O/ha plus a single spray of kinetin at 10 DAF resulted in higher accumulation of protein in the 'sink'.

7. The potassium-kinetin interaction was synergestic on the panicle protein and total protein yeild. Application of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF was found to be optimum in this respect.

8. The potassium-kinetin interactions were synergestic on nutrient uptake and application of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF resulted in higher uptake of N, P and K.

9. Number of panicles per m^2, number of spikelets per panicle, number of filled grains per panicle, percentage of filled grains and 1000 grain weight were the highest with the treatment combination "70 kg K_2O/-ha plus a single spray of kinetin at 10 DAF" followed by "35 kg K_2O/ha plus a single spray at 10 DAF".

10. The potassium-kinetin interaction was synergestic on grain yield and application of 35 kg K_2O/ha with a single spray of 10 ppm kinetin at 10 DAF was optimum.

11. Potassium application increased straw yield upto a level of 35 kg K_2O/ha. Kinetin spray (10 ppm) at 10 DAF increased straw yield.

12. The harvest index of rice was increased by potassium application. Application of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF resulted in higher harvest index.

Application of 35 kg K_2O/ha along with a single spray of 10 ppm kinetin at 10 DAF was an efficient and economic combination potassium and kinetin for low land rice during summer.

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* Original not seen.

APPENDICES

APPENDIX - I

METEOROLOGICAL DATA DURING THE CROPPING PERIOD
Summer 1987

Standard Weeks	Period From	Period To	Rainfall mm	Maximum temperature °C	Minimum temperature °C	Relative humidity(%) 08.30	Relative humidity (% 17.30
7	Feb. 12	Feb. 18	0	33	23.4	81	69
8	Feb. 19	Feb. 25	0	32.6	23.5	76	66
9	Feb. 26	Mar. 4	0	32.8	23.4	75	64
10	Mar. 5	Mar. 11	0	33.3	23.2	72	60
11	Mar. 12	Mar. 18	4	33.9	25.4	73	68
12	Mar. 19	Mar. 25	3.9	33.4	24.3	74	67
13	Mar. 26	Apr. 1	0	33.8	25.0	75	64
14	Apr. 2	Apr. 8	10.1	33.7	25.5	75	72
15	Apr. 9	Apr. 15	0	33.9	26.6	74	69
16	Apr. 16	Apr. 22	89	33.5	24.5	83	80
17	Apr. 23	Apr. 29	17.9	32.8	25.4	81	73
18	Apr. 30	May 6	14.5	33	25.3	77	67
19	May 7	May 13	2.6	34.2	25.8	76	70
20	May 14	May 20	94	32.7	24.5	83	83
21	May 21	May 27	85.4	32.9	24.8	85	76
22.	May 28	Jun. 3	35.9	32.0	24.9	80	75
23.	Jun. 4	Jun. 10	31.2	33.5	23.6	83	77

APPENDIX II

Abstract of ANOVA table for growth characters.

Source	d.f.	Mean Sum of Squares					
		Plant height		No. of tillers/M^2		Dry matter production	
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
Replication	2	5.52	37.3	578.25	877.5	133312	160128
Treatment	3	190.18**	322.9**	51810.6**	87365**	5370220**	9101483**
Error	42	5.55	9.48	335.9	896	242551	492989

Source	d.f.	MSS	
		Plant Height at Harvest	DMP at Harvest
Replication	2	27.52**	1030400
Treatments	15	10.58**	8001400**
Levels of K	3	33.52**	21656240**
Levels of B	3	12.07**	14144340**
Levels of K x Levels of B	9	2.43	1402141*
Error	30	2.47	580625.1

* Significant at 5% level

** Significant at 1% level

DAT - Days after transplanting

APPENDIX III

Abstract of ANOVA table for LAI, chlorophyll content, carbohydrate content and carbohydrate yield.

Source	d.f.	LAI at flowering	MEAN SUM OF SQUARES												
			Chlorophyll content				Carbohydrate content at harvest (%)				Carbohydrate yield at harvest				
			Source	d.f.	15 DAF	25 DAF	Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	Total
Replication	2	0.0188	Replication	2	0.00061	0.0024	0.00691*	0.00172	0.0051	6.195	20.585*	13.640	70.570	128528	139712
Treatments	3	7.427**	Treatments	15	0.0183**	0.0103**	0.1109**	0.0758**	0.1537**	54.545**	18.650**	24.980**	94.478**	1860499**	1897822**
Error	42	0.0255	Levels of K	3	0.0730**	0.0445**	0.4801**	0.2325**	0.6908**	210.322**	16.832**	27.507*	34.166	5856395**	5908182**
			Levels of B	3	0.0079**	0.0059**	0.0632**	0.0539**	0.0531**	40.302**	45.248**	65.494**	286.198**	2646080**	2746091**
			Levels of K x Levels of B	9	0.0035**	0.00035	0.00384	0.0308**	0.0082	7.368*	10.390	10.632	50.675	266673**	278279*
			Error	30	0.00052	0.00069	0.00199	0.0015	0.005	2.935	6.170	8.250	29.396	69080	73568

* Significant at 5% level

** Significant at 1% level

DAF - Days after flowering

APPENDIX IV

Abstract of ANOVA table for protein content, protein yield and nutrient uptake.

Mean Sum of Squares

Source	d.f.	Protein content at harvest				Protein yield at harvest					Nutrient uptake at harvest		
		Leaf	Sheath	Culm	Panicle	Leaf	Sheath	Culm	Panicle	Total	N	P	K
Replication	2	0.0261	0.0038	0.0146	0.237	90.351	20.011	354.453	189	1582	37	2.6	16.9
Treatments	15	0.1341**	0.0321**	0.0343	5.979**	100.945**	66.814**	540.686*	54716**	72725**	1801**	90.6**	3197.2**
Levels of K	3	0.4465**	0.0989**	0.0523	18.782**	140.840**	141.458**	912.250*	162438**	210034**	5609**	218.7**	6716.7**
Levels of B	3	0.0761**	0.0192**	0.0133	7.661**	229.286**	149.862**	645.916	82694**	118704**	2465**	96.2**	2655.5**
Levels of K x Levels of B	9	0.0493**	0.0140**	0.0338	1.152**	44.864	14.250	381.753	9483**	11629**	310**	46.0**	635.0**
Error	30	0.0158	0.0024	0.0188	0.083	21.943	9.603	256.853	1116	2209	40	3.1	9.5

* Significant at 5% level

** Significant at 1% level

APPENDIX V

Abstract of ANOVA table for yield attributes, yield, harvest index and economics of rice production.

Source	d.f.	No. of panicles/m^2	Panicle length	No. of spikelets/ panicle	No. of filled grains/ panicle	% filled grains	1000 grain weight	Grain yield	Straw yield	Harvest index	Economics of rice product: Net return	Economics of rice product: Net return per rupee invested
		Mean Sum of Squares										
Replication	2	33	0.085	0.766	0.515	1.266	0.016	163264	395776	0.00014	1237632	0.047
Treatments	15	11019**	3.997**	179.444**	458.444**	150.863**	8.414**	2462473**	1619200**	0.00079**	11256510**	0.364**
Levels of K	3	46461**	12.662**	783.146**	2106.604**	700.323**	38.106**	7194198**	3881813**	0.00278**	37850800**	1.377**
Levels of B	3	4868**	3.376**	64.208**	130.188**	37.042**	3.315**	3966933**	3151616**	0.00051**	11567450**	0.166**
Levels of K x Levels of B	9	1255**	1.317	16.622**	18.476**	5.649**	0.216**	383744*	354190	0.00022**	2288100*	0.093*
Error	30	70	0.727	2.397	1.928	1.845	0.066	127880	172654	0.00005	834577	0.033

* Significant at 5% level

** Significant at 1% level

GROWTH AND YIELD OF RICE AS INFLUENCED BY POTASSIUM AND KINETIN

By

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ABSTRACT OF THE THESIS
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ABSTRACT

With a view to study the effect of potassium and kinetin on growth, asssimilate partitioning, nutrient uptake and yield of a short duration rice variety Triveni, an experiment was conducted at the Cropping Systems Reasearch Centre, Karamana, Trivandrum during summer 1987. The soil of the experimental field was sandy loam, acidic in reaction, low in available nitrogen and potassium and medium in available phosphorus. The treatments consisted of a factorial combination of 4 levels of potassium (0, 17.5, 35 and 70 kg K_2O/ha) and 4 levels of kinetin (water spray, 10 ppm kinetin at flowering, 10 ppm kinetin at 10 DAF and 10 ppm kinetin at flowering and again at 10 DAF). The experiment was laid out in a randomised block design with three replications. An abstract of the results is given below.

The effects of potassium and kinetin were synergestic on growth, yield and nutrient uptake of rice and a combination of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF was optimum.

Both potassium as well as kinetin application prevented the accumulation of carbohydrate and proteins in the 'source' and enhanced their accumulation in the economic 'sink'. Their interaction effect was also favourable in this respect and 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF was optimum.

The harvest index of rice was favourably influenced by potassium, kinetin as well as their interactions. Application of 35 kg K_2O/ha plus a single spray of 10 ppm kinetin at 10 DAF resulted in higher grain yield as well as harvest index.

Application of 35 kg K_2O/ha along with a single spray of 10 ppm kinetin at 10 DAF was found to be an efficient and economic combination of potassium and kinetin for low land rice.