# EFFICACY OF SILICON AND POTASSIUM IN THE AMELIORATION OF IRON IN RICE CULTURE

By

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**THESIS**

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# DECLARATION

I hereby declare that this thesis entitled "**Efficacy of silicon and potassium in the amelioration of iron in rice culture**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

Certified that this thesis, entitled "**Efficacy of silicon and potassium in the amelioration of iron in rice culture**" is a record of research work done independently by **Mr. K. Lakshmikanthan,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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**K. Lakshmikanthan**

Dedicated to

*குறள் 1031*

சுழன்றும்ஏர் பின்னது உலகம் அதனால்
உழந்தும் உழவே தலை.

- *திருவள்ளுவர்*

Kural 1031

However they roam, the world must follow still the plougher's team; Though toilsome, culture of the ground as noblest toil esteem.

- Thiruvalluvar

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# INTRODUCTION

# INTRODUCTION

Sustainability of crop production can be considered as a reflection of the capability of the variety cultivated and efficiency of the inputs used in cultivation. The post green revolution era in food crops witnessed evolution of a number of varieties with high yield potential which in turn had lead to a sudden quantum jump in productivity. However the rate of enhancement in productivity could not be maintained and the gap between realisable and realised yields continue to be very wide. Failure to exploit the potential of varieties can only be attributed to inadequacies in management. As such it calls for critical appraisal of all the aspects of currently followed management system.

The problem of low yield expression in rice is of particular significance in the laterite soils of Kerala state. Laterites occupy more than 60 per cent of rice soils of the state. The average yield of rice in the state is only 2032 kg $ha^{-1}$ as against 4404 kg $ha^{-1}$ of Tamil Nadu (Siddiq, 2000). Comparatively very low average in the state can be attributed to the low yield of rice in the midland lateritic belt of the state. Investigations conducted in the state have shown that the problem of low productivity of rice is further confounded with poor response to sources and higher levels of fertilizers (Anilakumar *et al* 1992).

Experiments undertaken to find out the factors limiting response to inputs have shown that high contents of iron in the soil (Hassan, 1977) and its enhanced uptake (Potty *et al* 1992) is one of the prime causes. Musthafa and Potty (1996) reported that widening N/Fe ratio should help in containing the effects of excess iron.

Bridgit (1999) found that application of potash beyond 60 kg $K_2O$ $ha^{-1}$ increase the yield of rice in laterite soils. She also reported that sodium silicate application increases the yield of rice. It also reduced the removal of K by the crop. Moreover silica is considered a beneficial element in rice culture as it is capable to reduce the uptake of Fe and Mn. These results necessitated detailed investigation on the interacting influences of these elements as well as finalisation of optimum levels of application.

Efficiency of any source of input is governed by availability of the components as well as the sphere of influence and levels of application. Sodium silicate is a chemical and is easily and immediately reactive. Rice husk is a silica source but its availability may be delayed due to delay in decomposition. Benefit of silica from rice husk may be available only at later stage. Fine silica is insoluble and its effect may be external in nature.

Present recommendation in vogue recommends application of only 35 kg $K_2O$ $ha^{-1}$. Reports of higher requirement necessitated fixing of the optimum requirement of potash. The present experiment has been planned in this context. Specific objectives of the trial shall be listed as follows.

1. To evaluate the efficacy of silicon and potassium in ameliorating the stress influences of excess iron on rice productivity in laterite soils.
2. To characterise their influences on growth and yield of rice.
3. To find out the optimum level of application of K to rice in laterite soil.
4. To find out the ideal source and level of silica for management of rice.
5. The nature pattern and extent of interaction between silica and K.

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

Laterite soils of Kerala are characterised by low fertility and poor response to fertilizers. High yielding rice varieties often fails to express their yield potential in laterite soils. It is mainly attributed to different nutrient stresses particularly that of Fe and Mn. Amelioration of such nutrient stresses can significantly improve the productivity of rice in laterite soils of Kerala. The results of previous works on nutrient stress in laterite soils and their amelioration through the application Si and K is briefly reviewed in this chapter.

## 2.1 Yield limiting factors of laterite soils

The productivity of rice in laterite soils is seriously affected because of several limiting factors associated with these soils. This includes the characteristic physico-chemical properties of these soils, including nutrient toxicities.

According to Patnaik (1971), low productivity of laterite and allied soils can generally be attributed to low pH, low base saturation, low available P and high P fixing capacity and toxicity of Fe and Al. He further reported that moderate to high acidity of laterite soils also causes serious problems in major rice growing areas.

Hassan (1977) reported that the content of $Fe_2O_3$ in laterite soils of Kerala varied between 6 to 9 per cent.

Rajagopal *et al.* (1977) found that the available Mn content of Kerala State ranged from 0.2 to 20 ppm.

Amma *et al.* (1979) noted that 1N KCl exchangeable Al in rice soils of Kerala ranged from 85 to 3700 ppm and water soluble Al from 1 to 16 ppm.

Jacob (1987) reported that the contents of organic carbon and N, CEC and C:N ratio was low in laterite soils. He also observed very low total reserves of CaO, MgO, $K_2O$ and $P_2O_5$.

Potty *et al.* (1992) revealed that high absorption of iron by rice is the cause of low yield as well as poor input use efficiency in laterite soils.

Bridgit *et al.* (1993) were of the opinion that unfavourable cationic relation is the yield limiting component in laterite soils.

Musthafa and potty (1996) found that rice crop absorbed very large quantities of iron in laterite soils which, inspite of dilution with growth, has remained above the higher critical level of 300 ppm and accumulation of toxic levels of iron is an yield limiting factor.

Pushparajah (1998) opined that deficiency of cations is the major constraint for crop production in laterite soils. Intensive leaching leads to deficiency of N, P, K, Mg, Zn and other bases in these soils. Fixation of P also results in the deficiency of phosphorus.

According to Sehgal *et al.* (1998), water erosion is the major contributing factor for the low plant available water capacity of laterite soils, causing moisture stress or droughtness during the crop growing period. They also found that surface crusting restricts infiltration, seedling emergence and root proliferation in these soils.

## 2.2 Nutrient toxicity in rice culture

Somer and Shive (1942) reported that excess Mn hinders the translocation of Fe by causing Fe in the plant root to be converted into an insoluble form.

A study conducted by Moormann (1963) under acid sulphate soils showed that excess manganese concentration and its increased solubility causes toxicity to rice plant.

Cate and Sukhai (1964) found that young seedlings of rice suffered from 0.5 to 2 ppm dissolved Al while 3 to 4 weeks old plants suffered from > 25 ppm Al.

Iron and Mn chlorosis in paddy due to excess iron and Mn was reported by Karim and Mohsin (1964).

Ota (1968) found that poor development of lateral roots and root hairs and the development of lion tail roots are often observed in plants grown under iron toxic conditions. He also noted that bronzing of paddy was due to high Al content and Ca deficiency.

IRRI (1972) reported that excess iron led to bronzing in laterite soils of India, Ceylon, Thailand, Malaysia and Combodia.

Poor crop growth in acid soils was due to Al saturation of the soils and that pH had no effect in plant growth except at values below 4.2 (Black, 1973).

Iron in an important micronutrient but its excess concentration affects the growth and yield of rice in laterite soils of Kerala.Howeler (1973) indicated that iron induced deficiency of P, K, Ca and Mg can occur due to the relatively high level of iron in soil solution. He also found that root became coated with the iron oxide and reduces the root's capacity to absorb enough plant nutrients from an already deficient environment.

Thawornwong and Diest (1974) observed that the concentration of 2 ppm Al was lethal only to young rice seedlings and the plants which had passed seedling stage were not affected.

Vorm and Diest (1979) found that precipitation of manganese phosphate on the roots is likely to occur at high concentrations of Mn and P in the medium. They also observed that the early symptoms of chlorosis in rice leaves may be caused by high levels of Mn in leaves. The symptoms of chlorosis, often ascribed to Fe deficiency, are in fact caused by Mn excess.

Mengel and Kirkby (1982) observed that K deficiency is accompanied by Fe toxicity and high levels of Fe depressed K absorption leading to low productivity of rice in soils rich in Fe.

Blamey *et al.* (1983) also found that Al in solution markedly reduced root elongation as well as absorption and translocation of nutrients to the plant tops.

In a solution culture experiment, Abraham (1984) found that with increase in the Al concentration the root elongation was affected. He also found that at 40 ppm level of Al, shortening and branching of roots and onset of anatomical modifications were more conspicuous. A high level of Al affects cell division and reduces uptake of P, Ca and K.

Anilakumar *et al.* (1992) noted accumulation of an extraordinary high level of iron in rice in early stages but the content declines as growth advances. The sluggish growth rate observed in early stages as well as incomplete metabolism of N may at least in part be due to this excess Fe.

High content of iron in plants leads to degradation of chlorophyll 'a' which has been identified as the physiological cause of low productivity (Bridgit and Potty, 1992).

Singh (1992) found that Fe toxicity caused fewer panicles and filled grains, delayed crop maturity and yield reduction of 1 to 2.0 t $ha^{-1}$.

Bridgit *et al.* (1993) reported that yield expression in rice is inhibited in laterite soils due to their susceptibility to excess iron.

Musthafa and Potty (1996) have reported that high nitrogen absorption and resultant narrow N/Fe ratio leads to low productivity of rice.

## 2.3 Effect of Si on rice culture

### 2.3.1 Effect on growth attributes

Increase in the dry matter, height, length of earhead and roots due to the application of Si has been reported by Okamoto (1957).

Padmaja and Verghese (1966) found that application of sodium silicate as soil amendment in laterite soil increased the tillering, height of plants and the depth of penetration of the root system and the proportion of thicker to thinner roots.

The leaf blades are the main organ of photosynthesis and the flag leaf contributes significantly to the yield. Takahashi *et al.* (1966) noticed that silicon promotes $CO_2$ assimilation in the leaf blades and translocation of assimilated products to the panicle.

Sadanandan and Verghese (1968) reported application of Si in laterite soil increased the tillering capacity and led to better root development. They also found that application of sodium silicate performed better at the initial stage in increasing the number of tillers, but application of calcium magnesium silicate performed better at the later stages.

Ma *et al.* (1989) reported that the application of Si at various growth stages of rice increased the plant height and root dry weight. But Si applied at ripening stage have no effect on growth attributes.

Yamauchi and Winslow (1989) found that increased dry matter production in rice was increased by the application of sodium silicate in highly weathered and leached ultisols of Nigeria.

Ma and Takahashi (1990) reported that the dry weight of shoots increased with Si at all P levels, but the increase was not caused by the promotion of P uptake.

According to Agaric *et al.* (1992), the maintenance of photosynthetic activity due to Si fertilization could be one of the reasons for the increased dry matter production.

According to Tisdale *et al.* (1993), Si increases top length, number of stems and fresh and dry weight of rice and also increases photosynthesis because of better light interception.

2.3.2 Effect on yield attributes

Hosoda and Takota (1957) recorded 14 per cent increased yield in rice due to application of calcium silicate in soils of low $SiO_2/Al_2O_3$ ratio.

Padmaja and Verghese (1966) reported the following benefits due to the application of silicate materials to the soil.

a) Application of sodium silicate combined with magnesium carbonate increased all the productive factors such as earhead length, thousand grain weight, grain and straw yield.
b) Si reduced flowering duration to the extent of 10 days. Early flowering saves time and helps uniform and early ripening of grain.
c) Grain to straw ratio was maximum with Mg in combination with Si.
d) Ca in combination with Si has reduced the proportion of immature to mature earheads.

Vijayakumar (1977) observed that application of 600 kg $ha^{-1}$ of magnesium silicate increased the number of spikelets, number of filled grains and thousand grain weight.

Yein *et al.* (1983) suggested that the spreading of rice hull at 20 t $ha^{-1}$ about one week before planting increased the grain yield from 7.2 to 8.2 t $ha^{-1}$. Increased rice yield by application of rice husk has been reported by many researchers (Su, 1982; Tschen *et al.*, 1983; and Jakhro, 1984).

Snyder *et al.* (1986) showed that calcium silicate application increased rice yield on histosols mainly due to the supply of plant available Si and not due to supply of other nutrients.

Ditsathapom *et al.* (1989) reported that amendment of a saline-acid soil by rice hull ash increased rice yield only in the first year of application.

Ma *et al.* (1989) found that when Si was withheld during the reproductive stage, the dry weights of straw and grain was decreased by 20 and 50 per cent respectively. When Si was added at this stage the dry weights of straw and grain increased by 243 and 30 per cent respectively, compared with those of the plants cultured with Si throughout the growth period. But the effect of Si on the dry weights of straw and grain was small when Si was either added or withheld during the vegetative and ripening stages.

According to Bridgit (1999), application of sodium silicate at 250 kg $ha^{-1}$ in laterite soil significantly increased the yield of grain and the increase was to the tune of 619 kg $ha^{-1}$.

### 2.3.3 Effect of Si on chemical composition of rice

#### 2.3.3.1 Content of Si

Islam and Saha (1969) reported that Si application to nutrient culture solution increased Si concentrations of one month old rice plants. They also found that the Si content of rice plants harvested at earlier dates were relatively less than that of the plants harvested at latter dates.

Nayar *et al.* (1982) concluded that the Si content and uptake by plant increased with progress of growth from transplanting to harvest.

Ma *et al.* (1989) found that about 66 per cent Si in the whole plant and 70 to 75 per cent of Si in the leaf blades were absorbed during the reproductive stage and 75 per cent of Si in the panicle was absorbed during the ripening stage. They also reported that 40 to 50 per cent of the Si absorbed during the vegetative and reproductive stages was present in the leaf blades, whereas only 20 to 30 per cent of Si absorbed during the ripening stage was present in the leaf blades.

According to Subramanian and Gopalswamy (1990) significant increase in Si content both in grain and straw was observed by the addition of various silicate materials. They also noticed that among the various silicate materials rice husk ranked first in influencing the Si content in grain as well as straw.

Takahashi (1997) reported that rice is known to be a Si accumulator and Si had the fastest uptake rate among nutrients in solution. He also noted that rice roots actively absorb Si and stocks the absorbed Si in the top, mainly leaf blades and chaffs.

2.3.3.2 Content of K

Takijima *et al.* (1959) noticed an increase in the uptake of potassium by the application of Si.

Islam and Saha(1969) reported that the application of Si along with other nutrients in the culture solution has decreased the potassium uptake of rice plants. This is due to more absorption of Ca and Mg ions promoted by Si application.

Padmaja and Varghese (1972) found that percentage of potash in the grain and straw was maximum in those treatments, which included Si.

Bridgit (1999) reported that application of Si at 250 kg $ha^{-1}$ limited K removal by the crop within the level of application.

2.3.3.3 Content of N and P

Mitsui and Takatoh (1963) suggested that Si application lowered the N content in the leaves of rice plant, but had little or no effect on P and K contents.

Wagava and Kashima (1963) observed that when Si was applied, the percentage of nitrogen in every part of the rice plant was decreased.

IRRI (1965, 1966) reported that with no applied P, Si fertilization increased the P content of the rice straw and grain during wet and dry seasons. The increase in P content was attributed to the better availability of soil P and /or enhanced mobility of P from the roots to the stems.

Padmaja and Verghese (1972) found that application of Si as sodium silicate, reduce the nitrogen uptake. They also revealed that when Si was combined with Ca or Mg or both, the capacity of these nutrients for increasing the nitrogen uptake is reduced.

Elawad and Green (1979) reported that yield decreases when N rates are more than optimum. Due to a synergistic effect, application of Si has the potential to raise the optimum N rate, thus enhancing productivity of existing lowland rice.

Ma and Takahashi (1989) found that P uptake was markedly decreased and plant growth was promoted when Si was added to a culture solution containing high P.

Savant and Sawant (1995) also observed increased P content in rice seedlings when black-gray ash of rice hull at 0.5-2.0 $kg/m^2$ was applied to rice.

According to Takahashi (1997), nitrate ion among anions and ammonium ion among cations decreased the amount of Si uptake substantially. He also found that Si enhanced the effect of an additional supply of ammonium nitrogen.

2.3.3.4 Content of Ca, Mg and Zn

Wagava and Kashima (1963) in a detailed study on Si nutrition observed that the Ca content was decreased in the earheads, leaf blades and stalks by Si.

Islam and Saha (1969) reported that Si application promoted the uptake of cations (Ca and Mg) by rice plants. This indicated that the use of anions (Si) tended to increase the uptake of cations (Ca and Mg).

Takijima *et al.* (1970) noted that Si application resulted in increased uptake of Mg by rice.

Application of Si as sodium silicate increased the Zn content of root and shoot of rice as reported by Bridgit (1999).

2.3.3.5 Content of Fe, Mn and Al

The Si content of the rice plant affects the uptake of iron. As the content of Si in the tops increased over the range from 0.2 to 7.0 per cent $SiO_2$, decreasing amounts of iron were absorbed (Okuda and Takahashi, 1962).

According to Ponnamperuma (1965), sufficient Si supply facilitates oxygen transport more efficiently from the plant tops to the roots through enlargement or rigidity of gas channels and as a result increases oxidation and subsequent deposition of Fe and Mn on the root surface, thus excluding them from absorption by the plants.

Vorm and Diest (1979) found that Mn uptake increased with increasing pH but Si had a suppressive effect on Mn uptake.

Horiguchi (1988) reported that alleviation of Mn toxicity by Si is due to the following factors.

a) The increased oxygen power of roots causing Mn deposition on them
b) The decreased transpiration reduces the Mn absorption
c) The increased tolerance to an excess amount of Mn in the plant tissues

Savant *et al.*(1997) reported the possibility of formation of alumino silicate compounds in the walls of root cortex cells which inhibits the uptake of Al into the protoplast and reduces Al toxicity.

Wallace (1992) found that application of Si decreases the uptake of Fe in iron rich acid soil. This is because high concentrations of Si in rice plants could serve to creat an alkaline rhizosphere that would decrease the availability of the Fe. He also found that increased uptake of Si as an anion could be a potent force in decreasing the availability of Al, providing tolerance under acid soil conditions.

2.3.4 Effect of Si on pest and disease incidence

Chandramony and George (1975) found that application of sodium silicate induces anatomical changes favourable for lodging resistance to variety Ptb-31.

Mathai *et al.* (1981) found that application of Si at 250 and 500 kg $ha^{-1}$ as sodium silicate had significant effect in reducing the disease intensity on the $75^{th}$ day of sowing.

IRRI (1991) found that Si cells in epidermal layers of leaves were more closely packed than those in susceptible rice and contributed to physical resistance through enhanced mandibular wear in leaf folder larvae.

Sawant *et al.* (1994) found that improving Si concentration of rice plants reduces stem borer incidence. It is believed that the formation of a silicated epidermal layer prevents the physical penetration by insects and makes the plant cell less susceptible to enzymatic degradation by fungal pathogens.

Several authors reported that improved Si nutrition suppresses rice diseases, brownspot (Datnoff *et al.*, 1992), sheath blight (Datnoff *et al.*, 1990) and stem rot (Elwad and Green, 1979).

## 2.4 Effect of K on rice culture

### 2.4.1 Effect on plant growth and yield

According to Vijayan and Sreedharan (1972) application of graded levels of K increased the height of the plants, percentage of filled grains and thousand grain weight. They also found that application of 20 kg $ha^{-1}$ of K level had recorded the maximum grain and straw production.

The grain yield of rice increased with increase in level of K and the effect was linear upto 60 kg $K_2O$ $ha^{-1}$ (Robinson and Rajagobalan, 1977).

Tanaka *et al.* (1977) noted that the rice plant was characterised by its high absorbing as well as exhausting K and thereby tended to maintain the K concentration at a constant level. When the K concentration in the rice plant was forced to be low, its relative growth increment decreased drastically.

Agarwal (1980) also observed significant increase in the yield by the application of $K_2O$ upto 80 kg $ha^{-1}$.

Ray and Choudhari (1980) found that K increased the rate of translocation of aminoacids to the grain and rate of protein formation. They also noted the increase in chlorophyll content of flag leaf due to K application.

Nad and Goswami (1981) reported that 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.

Venkatasubbiah *et al.* (1982) indicated that significant increase in yield of grain and straw were obtained for applied potassium. According to them the effect of potash application was more on grain yield compared to straw yield.

Barthakur *et al.* (1983) confirmed that the application of 40 to 80 kg $K_2O$ $ha^{-1}$ could increase the grain yield of rice considerably over the control.

Mandal and Dasmahapatra (1983) reported that K absorbed at the maximum tillering stage increased the number of panicles, spikelets per panicle and grain weight. They also noted positive correlation between K application and leaf area index (LAI).

Gurmani *et al.* (1984) reported a significant increase in grain yield with increase in the level of K from 0 to 83 kg $K_2O$ $ha^{-1}$.

According to Bridgit (1999) increasing levels of K significantly increased the height of the plant at panicle initiation, flowering and harvesting stages but the increasing the levels of $K_2O$ beyond 120 kg $ha^{-1}$ did not have any effect. She also found that application of K @ 120 and 180 kg $ha^{-1}$ significantly increased the panicle weight, filled grains per panicle and grain weight as compared to 60 kg $K_2O$ $ha^{-1}$.

2.4.2 Effect on nutrient uptake and content

Ishizuka and Tanaka (1950) reported small increases in the concentration of Silicon in the rice plant with increasing supply of K.

Nogushi and Sugawara (1966) found that K deficiency reduced the accumulation of Silicon in the epidermal cells of the leaf blades.

Sahu (1968) found that high K content of leaf decreased the bronzing in rice caused by excess Fe and increased the K:Fe ratio.

Vijayan and Sreedharan (1972) observed that the content of K in the grain and straw were highest at the maximum level of 20 kg $ha^{-1}$ of $K_2O$ applied. They also found that a progressive increase in K content of grain and straw with graded doses of K but the grain and straw yields were not progressively increased.

A consistent decrease in the Mn content of rice plants with increasing levels of K has been reported by Randhawa and Pasricha (1976).

According to Reddy *et al.* (1978) N uptake increased with increase in the application of K from 50 to 100 kg $K_2O$ $ha^{-1}$.

Datta and Gomez (1982) confirmed that absorption of P was maximum at the flowering stage and the response to P was more when K was applied.

Singh and Singh (1987) found that the total uptake and percentage of translocation of N, P and K by rice increased significantly with increasing levels of K. They also found that Fe concentration was reduced drastically. The study indicated K-P synergism and K-Fe antagonism.

Chakravorti (1989) reported that application of K increased grain N content and total N uptake while P content was little affected. They also observed that applied K decreased Ca and Mg content in rice raised in alluvial soils.

Qadar (1989) observed that application of K in sodic soil reduced the concentration of Na in the shoots, which led to better ionic balance and increased growth and yield.

Mitra *et al.* (1990) noted that the application of higher levels of K (0 to 160 kg $ha^{-1}$) on rice in an iron toxic laterite soil decreased the Fe toxicity symptoms with increasing K levels.

According to Dixit and Sharma (1993), addition of K significantly reduced the concentration of Al, Fe and acidity of soil.

Sreemannarayana and Sairam (1995) stated that increasing K levels decreased leaf Fe and Mn contents and increased leaf Zn content slightly.

Bridgit (1999) reported that increased application of K in laterite soil increased the $SiO_2$ content in the grain and straw.

2.4.3 Effect on pest and diseases of rice

Israel and Rao (1967) reported that increasing levels of K application resulted in increase in the incidence of gall fly.

Padhi and Misra (1975) reported that application of 20 kg $K_2O$ $ha^{-1}$ was very effective in reducing occurrence of bacterial leaf blight.

According to Mukherjee (1976) K is very effective in reducing the fungal diseases because it helps to produce leaves possessing thicker cuticles and stronger epidermal cell walls which may prevent the entry of germinating spores.

Subramanian and Balasubramanian (1977) found that the application of K reduced the incidence of thrips and whorl maggot but had no effect on the leaf roller incidence.

Sekhon (1982) observed that the application of K reduced the incidence of bacterial leaf blight, sheath blight and bronzing of rice.

Application of K reduced the incidence of leaf roller, thrips, brown plant hopper and green leaf hopper but it had no effect on the stem borer and gall midge (Rao, 1985).

Lack of K in wet land rice increased the severity of foliar diseases such as stem rot, sheath blight and brown leaf spot (Tisdale *et al.*, 1993).

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The research project entitled "Efficacy of silicon and potassium in the amelioration of iron in rice culture" was undertaken at the Agricultural Research Station, Mannuthy during the virippu and mundakan seasons of 1999-2000. The particulars of materials used and methods adopted in the conduct of the experiments are presented in this chapter.

**Materials used**

**Location of experimental site**

The Agricultural Research Station, Mannuthy is located at 10°31' N latitude, 76°13' E longitude and at an altitude of 40.29 m above mean sea level. It is situated about six km East of Thrissur on the southern side of Thrissur-Palakkad National Highway No.47.

**Climatic conditions**

The area enjoys a typical humid tropical climate with mean maximum temperature of 31.6 $^0$C, mean minimum temperature of 23.4$^0$C and total annual rainfall of 2620 mm.

The mean weekly averages of the important meteorological parameters observed during the experimental period are presented in Appendix I and II and Fig.1a, 1b, 2a and 2b.

**Soil**

The soil of the experimental area belongs to laterite sandy clay loam under the oxisol group. The soils are acidic in reaction with a pH of 4.6.

The physico-chemical characteristics of the experimental site are presented in Table 1.

Fig. 1a. Weekly weather data during the first crop period (Temperature, Sunshine and Evaporation)

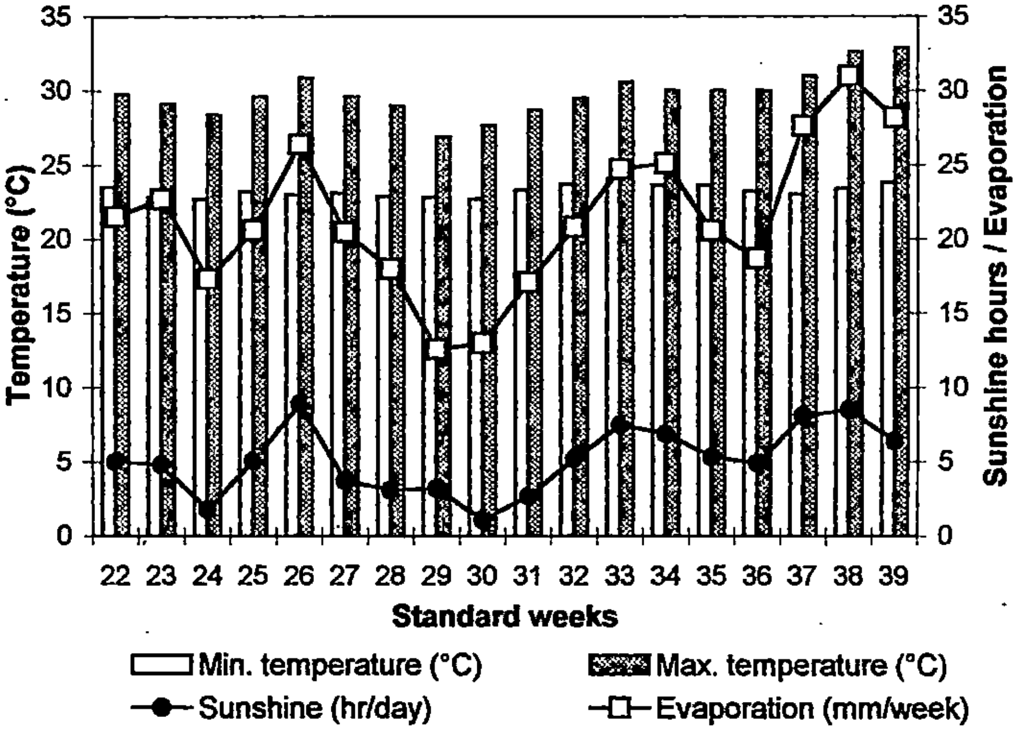



Fig. 1b. Weekly weather data during the first crop period (Relative humidity and Rainfall)

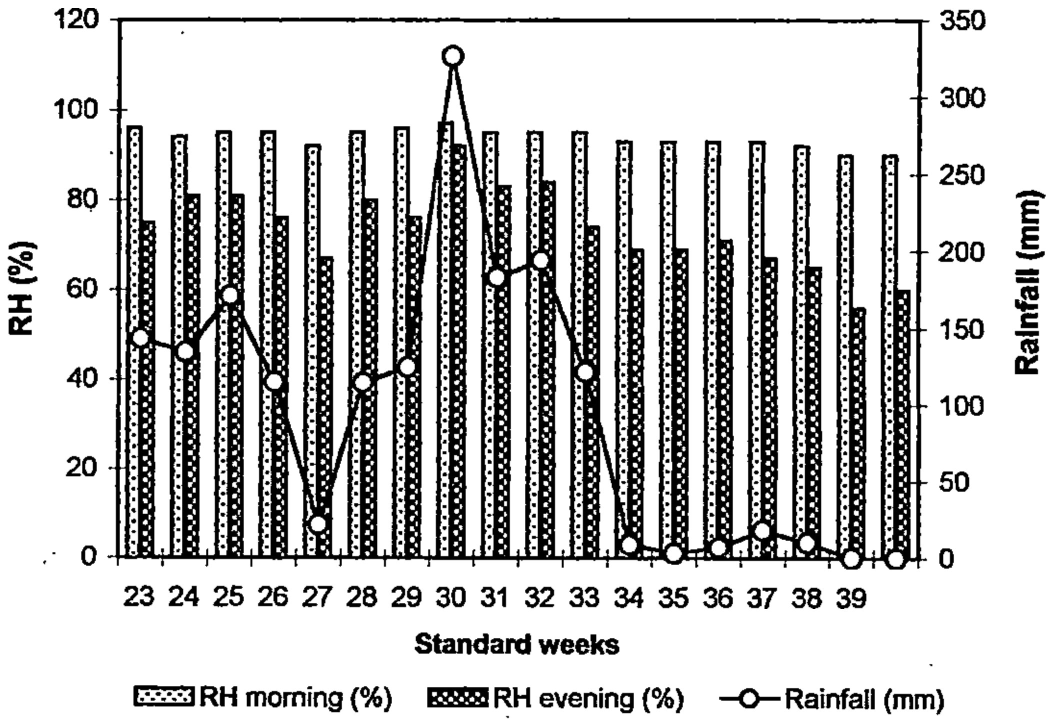


**Fig. 2a. Weekly weather data during the second crop period (Temperature, Sunshine and Evaporation)**

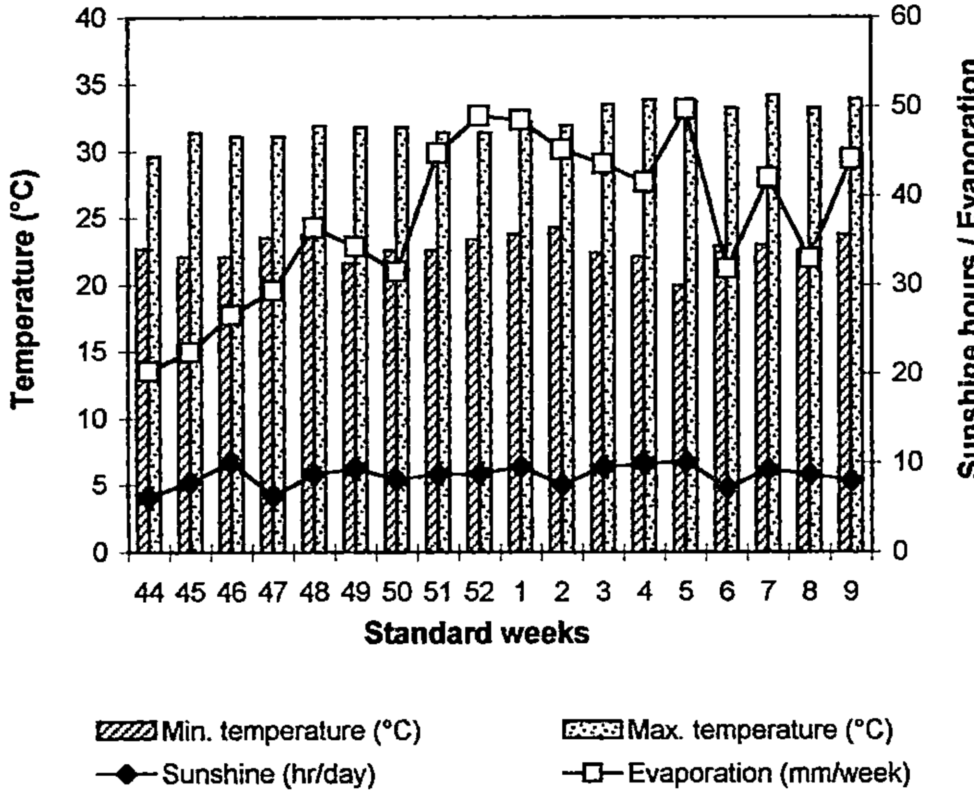



**Fig. 2b. Weekly weather data during the second crop period (Relative humidity and Rainfall)**

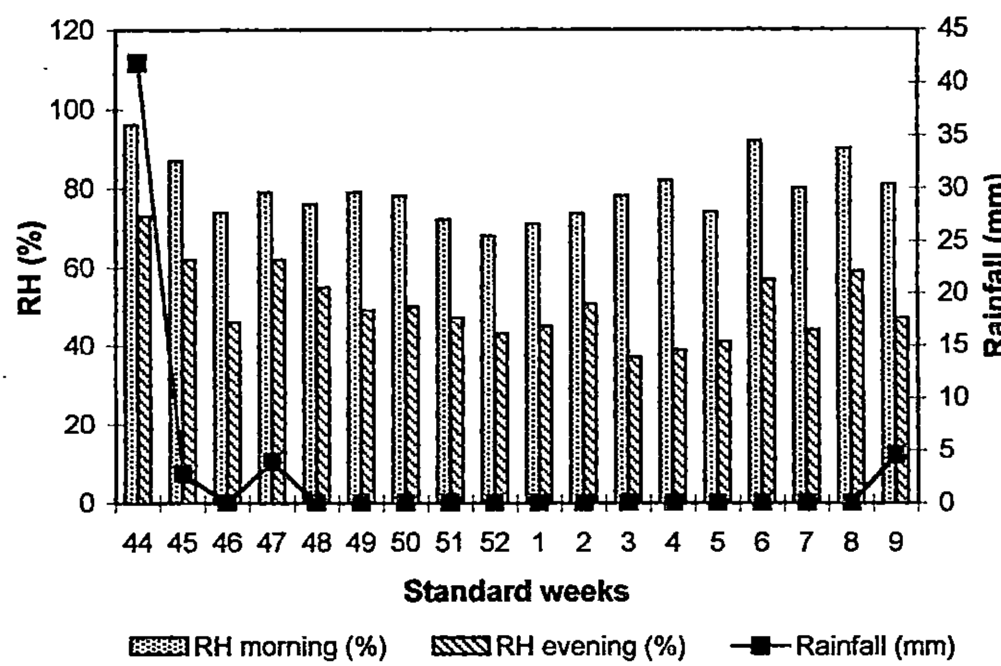


Table 1. Physico-chemical characteristics of the soil of the experimental site

| | |
|---|---|
| pH | 4.6 |
| Electrical conductivity (mmhos $cm^{-1}$) | 0.10 |
| Bulk density (g $cc^{-1}$) | 1.34 |
| Particle density (g $cc^{-1}$) | 2.38 |
| Porosity (%) | 49.07 |
| Water holding capacity (%) | 48.99 |
| Mechanical composition | |
| Sand (%) | 76.01 |
| Silt (%) | 4.41 |
| Clay (%) | 18.71 |
| Available nutrients | |
| Organic carbon | 0.66 |
| N (kg $ha^{-1}$) | 309.0 |
| P (kg $ha^{-1}$) | 33.0 |
| K (kg $ha^{-1}$) | 92.8 |
| Ca (kg $ha^{-1}$) | 148.0 |
| Mg (kg $ha^{-1}$) | 41.5 |
| S (kg $ha^{-1}$) | 289.2 |
| Na (kg $ha^{-1}$) | 92.4 |
| Fe (kg $ha^{-1}$) | 720.0 |
| Mn (kg $ha^{-1}$) | 42.2 |

**Crop and variety**

The rice variety used for the experiment was Jyothi, a red kernelled, short duration variety of 110-120 days duration. Jyothi is a variety suitable for direct seeding and transplanting during virippu (kharif) and mundakan (rabi) crop seasons, tolerant to blast and BPH, moderately susceptible to sheath blight and capable of producing an yield of more than 8 t $ha^{-1}$ under favourable situations and moderately good yields under stress conditions.

**Cropping history of the experimental site**

The experimental area belongs to a typical double cropped wet land. The field was under bulk cropping in the previous season.

**Experimental methods**

The main crop was taken during the virippu season and residual crop was taken during the mundakan season. Thirteen treatments in factorial RBD with three replications constituted the main crop. The plot size was 5.0 x 4.0 m and the spacing adopted was 15 x 10cm.The net plot size was 4.4 x 3.6m. The treatment details for the main crop are given below.

Treatments details

1. Sodium silicate to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
2. Sodium silicate to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$
3. Sodium silicate to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
4. Sodium silicate to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$
5. Fine silica to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
6. Fine silica to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$
7. Fine silica to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
8. Fine silica to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$
9. Rice husk to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
10. Rice husk to supply silica @ 250 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$

11. Rice husk to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 52.5 kg $ha^{-1}$
12. Rice husk to supply silica @ 500 kg $ha^{-1}$ and $K_2O$ @ 70 kg $ha^{-1}$
13. Control (35 kg $K_2O$ $ha^{-1}$)

The recommended dose of 70 kg N $ha^{-1}$ and 35 kg $P_2O_5$ $ha^{-1}$ was applied uniformly to all the treatments (KAU, 1996).

In the residual crop, two replications received only N and P. The third replication, which was again partitioned in to two, served as two replications, received K also as per the treatments, in addition to N and P.

**Fertilizers and amendments**

Urea, mussorie rock phosphate, muriate of potash, sodium silicate, fine silica and rice husk were used as the sources for the different nutrients. The content of the sources used in respect of the different nutrients is given in Table 2.

Table 2. Chemical composition of fertilizers and amendments

| Fertilizer/amendment | Nutrient | Nutrient content (%) |
|---|---|---|
| Urea | Nitrogen (N) | 46 |
| Mussorie rock phosphate | Phosphorus ($P_2O_5$) | 20 |
| Muriate of potash | Potassium ($K_2O$) | 60 |
| Sodium silicate | $SiO_2$ | 20 |
| Fine silica | ” | 100 |
| Rice husk | ” | 20 |

**Crop culture**

All the cultural operations were carried out as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1996).

Seeds of the variety Jyothi was obtained from the Regional Agricultural Research Station, Pattambi. Twenty three days old seedlings were transplanted from the nursery raised for the purpose in a well puddled and levelled field at a spacing of 15 x 10 cm @ 2-3 seedlings per hill. Date of nursery sowing, transplanting and harvesting of the two crops are given in Table 3.

Table 3. Sowing and harvesting dates of crop

| Particulars | First crop | Second crop |
|---|---|---|
| Date of sowing (nursery) | 1-6-99 | 30-10-99 |
| Transplanting date | 24-6-99 | 20-11-99 |
| Harvesting date | 28-9-99 | 28-2-2000 |
| Duration (days) | 118 | 121 |

The entire quantity of P and 2/3 of N were applied as basal and the remaining quantity of N was applied as top dressing at panicle initiation stage (KAU, 1996).

Potassium was applied as per the treatments, half as basal and half at panicle initiation stage.

According to the treatments the rice husk was applied 10 days before transplanting. Fine silica and sodium silicate were applied as basal.

During first crop (virippu), the crop was raised as rainfed crop while in second crop (mundakan) few irrigations were given at the later stages of the crop.

The details of plant protection measures adopted are given below

| Pest / Disease | Chemical with dose |
|---|---|
| Leaf roller | Quinalphos (1000 ml $ha^{-1}$) |
| Stem borer | Methyl dematon (1000 ml $ha^{-1}$) |
| Rice bug | Methyl parathion (500 ml $ha^{-1}$) |
| Sheath blight | Ediphenphos (0.1%) |

Hand weeding was done twice at 20 and 40 days after transplanting.

Experimental plots were harvested when matured. Plants in the two border rows on all sides of each plot were harvested first and removed. Net plots were harvested by cutting at the base. Threshing was done on the same day and fresh yields were recorded. Dry weight of grain and straw were recorded at 14 per cent moisture content.

**Observations recorded**

a. Growth and yield attributes and pest and disease incidence

Ten hills per plot, selected at random, served as the sampling unit for biometric observations.

| | Observations recorded | | Stage of observation |
|---|---|---|---|
| i) | Height of the plants (cm) | : | Maximum tillering, panicle initiation, flowering and harvesting stages |
| ii) | Tiller count (No./hill) | : | -do- |
| iii) | Dry matter production (g plant$^{-1}$) | : | -do- |
| iv) | Productive tillers (No./hill) | : | Flowering, milky and harvesting stages |
| v) | Length of panicle (cm) | : | Harvest |
| vi) | No. of spikelets per panicle | : | -do- |
| vii) | No. of filled grains per panicle | : | -do- |
| viii) | No. of chaff grains per panicle | : | -do- |
| ix) | Panicle weight (g) | : | -do- |
| x) | Grain yield (kg ha$^{-1}$) | : | -do- |
| xi) | Straw yield (kg ha$^{-1}$) | : | -do- |
| xii) | 1000 grain weight (g) | : | -do- |

xiii) Pest and disease incidence : Panicle initiation

b. Chemical analysis

For chemical analysis five hills were selected at random from each plot. Plant samples were collected at different growth stages (maximum tillering, panicle initiation, flowering and harvesting), dried in a hot air oven at 60 ± 5°C, powdered well and analysed for different nutrient contents (N, P, K, Ca, Mg, S, Na, Fe, Mn and $SiO_2$). The methods used for the analysis of different nutrients are given in Table 4. Ratios of the contents of different nutrients as well as their uptake at different growth stages were also worked out.

c. Other observations

| | | | |
|---|---|---|---|
| i) | Shoot:root ratio | : | Computed from dry weight of shoot and root |
| ii) | Grain:straw ratio | : | Computed from grain and straw yield |
| iii) | Nutrient uptake | : | Computed from nutrient content and dry matter accumulation |

**Soil analysis**

Soil samples were collected from the experimental plots before and after the first and second crop following standard procedures. Soil samples dried, powdered and passed through 2 mm sieve, were used for analysing physico-chemical characteristics of the soil. The various methods used for the analysis are given in Table 5.

**Statistical analysis**

Statistical analysis was done using the analysis of variance technique (Panse and Sukhatme, 1978). MSTATC and MS-Excel Softwares were used for computation and analysis.

Table 4. Methods used for plant nutrient analysis

| Sl.No. | Nutrient | Method | Reference |
|---|---|---|---|
| 1 | Nitrogen | Microkjeldhal digestion and Distillation method | Jackson, 1958 |
| 2 | Phosphorus | Vanadomolybdophosphoric yellow colour method using Spectronic 20 | " |
| 3 | Potassium | Diacid extract using flame Photometer | " |
| 4 | Calcium | Diacid extract using Atomic Absorption Spectrophotometer | " |
| 5 | Magnesium | " | " |
| 6 | Zinc | " | Hart, 1961 |
| 7 | Sulphur | Turbidimetric method using Spectronic 20 | Jackson, 1958 |
| 8 | Iron | Diacid extract using Atomic Absorption Spectrophotometer | " |
| 9 | Manganese | " | " |
| 10 | Silicon | Rapid microdetermination of silicon | Nayar *et al.*, 1975 |

Table 5. Methods used for soil chemical analysis

| Sl. No. | Analysis | Method | Reference |
|---|---|---|---|
| 1 | Soil reaction (pH) | Soil water suspension 1:2:5 and read in pH meter - Elico | Hesse, 1971 |
| 2 | Electrical conductivity (EC) | Soil water suspension 1:2.5 and read in digital conductivity bridge | Jackson, 1958 |
| 3 | Organic carbon | Walkely-Black method | ” |
| 4 | Available N | Alkaline permanganate method | Subbiah and Asija, 1956 |
| 5 | Available $P_2O_5$ | Ascorbic acid reduced molybdophosphoric blue colour Method | Watnabe and Olsen, 1965 |
| 6 | Available $K_2O$ | NN $NH_4$ Ac extract using Flame Photometer | Jackson, 1958 |
| 7 | Exchangeable Ca | NN $NH_4$ Ac extract using Atomic Absorption Spectro photometer | ” |
| 8 | Exchangeable Mg | ” | ” |
| 9 | Available S | $CaCl_2$ extract - turbidimetry Method | Chesnin and Yien, 1951 |
| 10 | Available Fe | DTPA extract method using Atomic Absorption Spectro photometer | Lindsey and Norvell, 1978 |
| 11 | Available Mn | ” | ” |
| 12 | Available Zn | ” | ” |

# RESULTS

# 4. RESULTS

Unavailability of applied and non applied nutrients, including major, secondary, micro and beneficial nutrients, is a serious yield limiting constraint in the laterite soils of Kerala. Sustainable productivity in laterite soils can be achieved only through the balanced availability of these nutrients in adequate quantity. A study entitled "Efficacy of silicon and potassium in the amelioration of iron in rice culture" was conducted in this background. The effect of various treatments, particularly that of silica and potash, on the growth, yield attributes and nutrient content of rice at different growth stages was studied in two field experiments and the results are presented in this chapter.

## 4.1 MAIN CROP

### 4.1.1 Effects of treatments on growth attributes

#### 4.1.1.1 Effects of treatments on morphological characters (Table 6)

*a. Sources of silica*

The data revealed that the different sources of silica significantly increased the plant height at all the stages of the crop growth except at panicle initiation stage. Among the three sources of silica, plant height was maximum with sodium silicate at all the growth stages except at maximum tillering. There was no significant difference between fine silica and rice husk.

Data on the number of tillers per hill showed that different sources of silica significantly affected the tiller count, with the highest in sodium silicate followed by fine silica and rice husk at all the growth stages except at harvest stage.

Significant variation in the number of productive tillers per hill was observed among the sources of silica at all the growth stages, with the maximum in sodium silicate followed by fine silica and rice husk.

**Table 6. Effects of treatments on morphological characters**

| Treatments | Plant height (cm) | | | | Tillers per hill (No.) | | | | | Productive tillers per hill (No.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MT | PI | Flg | HT | MT | PI | Flg | MS | HT | Flg | MS | HT |
| Control | 38.1 | 62.4 | 95.8 | 93.3 | 6.3 | 7.0 | 7.0 | 8.1 | 8.3 | 7.0 | 7.0 | 7.0 |
| Rest | 37.0 | 61.5 | 94.1 | 92.1 | 6.1 | 6.7 | 6.8 | 7.9 | 8.3 | 6.4 | 6.6 | 6.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | 0.2 | NS | NS |
| *Sources of silica* | | | | | | | | | | | | |
| Sodium silicate | 35.9 | 61.9 | 97.5 | 94.8 | 6.3 | 6.8 | 6.9 | 8.2 | 8.6 | 6.6 | 6.7 | 6.8 |
| Fine silica | 36.4 | 61.1 | 92.1 | 90.7 | 6.3 | 6.8 | 6.8 | 7.9 | 8.3 | 6.4 | 6.6 | 6.8 |
| Rice husk | 38.8 | 61.5 | 92.6 | 90.9 | 5.8 | 6.4 | 6.3 | 7.5 | 8.0 | 6.1 | 6.3 | 6.4 |
| CD (0.05) | 2.3 | NS | 2.1 | 1.5 | 0.4 | 0.3 | 0.3 | 0.5 | NS | 0.4 | 0.3 | 0.3 |
| *Levels of silica* | | | | | | | | | | | | |
| $Si_{250}$ | 38.0 | 62.5 | 92.3 | 91.8 | 6.2 | 6.7 | 6.7 | 7.9 | 8.2 | 6.4 | 6.6 | 6.6 |
| $Si_{500}$ | 36.0 | 60.4 | 94.7 | 92.4 | 6.1 | 6.7 | 7.0 | 7.8 | 8.4 | 6.4 | 6.7 | 6.8 |
| CD (0.05) | 1.9 | 1.2 | 1.7 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | |
| $K_{52.5}$ | 36.3 | 61.2 | 94.9 | 92.6 | 6.2 | 6.6 | 6.8 | 7.9 | 8.2 | 6.4 | 6.6 | 6.7 |
| $K_{70}$ | 37.7 | 61.7 | 93.8 | 91.7 | 6.1 | 6.7 | 7.1 | 7.9 | 8.3 | 6.4 | 6.5 | 6.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*b. Levels of silica*

Increasing the level of application of silica significantly decreased the plant height at maximum tillering and panicle initiation whereas an increase was noted at flowering.

*c. Levels of K*

Different levels of K had no significant effect on all the three morphological attributes at any of the growth stages.

4.1.1.2 Effects of treatments on dry matter production (Table 7)

The treatments were significantly superior over control in shoot dry weight at flowering and harvesting stages and the increases were to the tune of 37.0 and 35.5 per cent, respectively.

Significant difference in root dry weight between control and treatments was obtained only at flowering and the increase was 40.2 per cent.

a. Sources of silica

The shoot weight was significantly influenced by the three sources of silica at the flowering and harvesting stages.

Maximum shoot weight was recorded in sodium silicate and the increase was 19.1 and 9.0 per cent at flowering, 19.0 and 21.1 per cent at harvesting, over fine silica and rice husk respectively.

Root weight was significantly different among the three sources of silica at panicle initiation and flowering stages. At panicle initiation the root weight was maximum in rice husk followed by fine silica and sodium silicate. But at flowering stage the root weight was maximum in sodium silicate followed by rice husk and fine silica.

**Table 7. Effects of treatments on dry matter production (g/ plant)**

| Treatments | Maximum tillering | | | Panicle initiation | | | Flowering | | | Harvesting | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R |
| Control | 1.00 | 0.37 | 2.76 | 2.57 | 1.15 | 2.25 | 13.8 | 2.14 | 6.47 | 22.5 | 1.83 | 12.5 |
| Rest | 0.98 | 0.32 | 3.13 | 2.65 | 1.24 | 2.28 | 18.9 | 3.00 | 6.45 | 30.5 | 2.08 | 15.2 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 1.4 | 0.42 | NS | 2.9 | NS | NS |
| *Sources of silica* | | | | | | | | | | | | |
| Sodium silicate | 0.95 | 0.36 | 2.64 | 2.64 | 1.10 | 2.53 | 20.6 | 3.17 | 6.54 | 34.4 | 2.08 | 16.7 |
| Fine silica | 0.94 | 0.29 | 3.33 | 2.54 | 1.17 | 2.17 | 17.3 | 2.70 | 6.71 | 28.9 | 2.00 | 15.0 |
| Rice husk | 1.05 | 0.32 | 3.43 | 2.75 | 1.36 | 2.16 | 18.9 | 3.14 | 6.10 | 28.4 | 2.17 | 13.9 |
| CD (0.05) | NS | NS | 0.37 | NS | 0.17 | 0.29 | 1.0 | 0.28 | NS | 2.0 | NS | NS |
| *Levels of silica* | | | | | | | | | | | | |
| $Si_{250}$ | 0.97 | 0.31 | 3.20 | 2.69 | 1.30 | 2.15 | 17.7 | 2.89 | 6.20 | 27.3 | 2.08 | 13.5 |
| $Si_{500}$ | 0.99 | 0.33 | 3.07 | 2.61 | 1.14 | 2.42 | 20.1 | 3.12 | 6.70 | 33.8 | 2.08 | 16.9 |
| CD (0.05) | NS | NS | NS | NS | 0.14 | 0.24 | 0.8 | 0.23 | 0.42 | 1.6 | NS | 2.0 |
| *Levels of Potash* | | | | | | | | | | | | |
| $K_{52.5}$ | 0.95 | 0.32 | 3.14 | 2.60 | 1.11 | 2.40 | 18.6 | 2.90 | 6.50 | 29.3 | 2.10 | 14.4 |
| $K_{70}$ | 1.01 | 0.32 | 3.13 | 2.69 | 1.31 | 2.17 | 19.2 | 3.11 | 6.40 | 31.8 | 2.06 | 16.0 |
| CD (0.05) | NS | NS | NS | NS | 0.14 | NS | NS | NS | NS | 1.6 | NS | NS |

Shoot:root ratio was found to be wider with advances in crop growth and the three sources of silica significantly influenced the attribute at maximum tillering and panicle initiation stages.

*b. Levels of silica*

The levels of silica significantly influenced the shoot weight at flowering and harvesting. The shoot weight increased with increasing levels of silica and the increase was to the tune of 13.6 and 23.8 per cent, at flowering and harvesting respectively.

Root weight was significantly affected by the levels of silica only at panicle initiation and flowering stages. Root weight was highest at 250 kg $ha^{-1}$ level at panicle initiation stage and 500 kg $ha^{-1}$ level at harvest.

Shoot:root ratio was found to increase with increasing levels of silica at all the growth stages, except at maximum tillering stage.

*c. Levels of K*

Increased application of K significantly influenced the shoot weight only at flowering stage. Significant increase in root weight was observed only at panicle initiation stage with higher level of K.

Though root:shoot ratio showed a widening trend towards harvesting, it was significantly different only at panicle initiation stage between the levels of K.

4.1.1.3 Two factor interaction effects on growth attributes (Table 8)

*Interaction effect between sources and levels of silica*

The effect of silica on growth of rice varied with sources of silica and levels of application as well as the attribute under study and the variability had been statistically significant.

Increasing the level of application of sodium silicate increased the height of plants at flowering but decreased the root weight at all the three stages of observation. The decrease at maximum tillering, panicle initiation and flowering were to the tune of 18.0, 40.0 and 42.0 per cent compared to the lower level. Corresponding reduction in the shoot weight at panicle initiation was worked out to 18.8 per cent. Shoot weight was not affected at maximum tillering and flowering but shoot:root ratio was significantly increased by 25.0 and 16.0 per cent at panicle initiation and flowering stage.

Fine silica on the other hand reduced the number of tillers at panicle initiation by 7.0 per cent and productive tillers at harvest by 7.0 per cent. Increased root weight at flowering, shoot weight at panicle initiation and flowering were observed at the higher level and the increases were to tune of 18.2, 22.8 and 26.6 per cent, respectively, over the lower level. Significant increase in shoot:root ratio was also observed at flowering.

Application of silica through rice husk at 500 kg $ha^{-1}$ significantly increased the tiller count at panicle initiation and harvest stages by 8.1 and 13.0 per cent and productive tillers at harvest by 12.0 per cent. An increase in root and shoot weight of 23.0 and 14.0 per cent, respectively, was observed at flowering with higher level of silica.

*Interaction effect between sources of silica and levels of K*

Sodium silicate, with increasing level of K from 52.5 to 70 kg $ha^{-1}$, significantly increased the shoot weight at maximum tillering by 20.0 per cent but reduced it at flowering by 8.0 per cent. No other character was appreciably affected.

With increasing level of K, rice husk significantly reduced root weight at harvest and shoot:root ratio at maximum tillering and panicle initiation but

**Table 8. Two factor interaction effects on growth attributes**

| Treatments | Height at Flg (cm) | | Tillers per hill at PI (No.) | | Tillers per hill at HT (No.) | | Root wt at MT (g/ plant) | | Root wt at PI (g/ plant) | | Root wt at Flg (g/ plant) | | Shoot wt at MT (g/ plant) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 93.3 | 96.3 | 6.8 | 6.8 | 8.5 | 8.7 | 0.4 | 0.3 | 1.4 | 0.8 | 3.4 | 3.0 | 1.0 | 0.9 |
| Fine silica | 90.3 | 91.0 | 7.0 | 6.5 | 8.3 | 8.0 | 0.3 | 0.3 | 1.2 | 1.3 | 2.5 | 2.9 | 0.9 | 1.0 |
| Rice husk | 91.8 | 92.4 | 6.2 | 6.7 | 7.5 | 8.5 | 0.3 | 0.4 | 1.4 | 1.3 | 2.8 | 3.5 | 1.0 | 1.1 |
| CD (0.05) | 2.2 | | 0.5 | | 0.8 | | 0.1 | | 0.3 | | 0.4 | | 0.2 | |

| Treatments | Shoot wt at PI (g/ plant) | | Shoot wt at Flg (g/ plant) | | S/R at MT | | S/R at PI | | S/R at Flg | | Productive tillers at HT (No.) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 2.92 | 2.37 | 20.24 | 21.00 | 2.45 | 2.84 | 2.18 | 2.89 | 5.98 | 7.10 | 6.7 | 7.0 |
| Fine silica | 2.28 | 2.80 | 15.25 | 19.30 | 3.44 | 3.22 | 2.10 | 2.25 | 6.30 | 7.12 | 7.0 | 6.5 |
| Rice husk | 2.86 | 2.65 | 17.67 | 20.13 | 3.70 | 3.16 | 2.19 | 2.13 | 6.33 | 5.88 | 6.0 | 6.7 |
| CD (0.05) | 0.31 | | 1.38 | | 0.52 | | 0.41 | | 0.72 | | 0.4 | |

| Treatments | Shoot wt at MT (g/ plant) | | Shoot wt at Flg (g/ plant) | | Root wt at HT (g/ plant) | | S/R at MT | | S/R at PI | | S/R at HT | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.87 | 1.04 | 21.45 | 19.80 | 2.05 | 2.08 | 2.63 | 2.65 | 2.47 | 2.59 | 15.98 | 17.48 |
| Fine silica | 0.86 | 1.02 | 16.20 | 18.35 | 1.83 | 2.17 | 2.95 | 3.72 | 2.25 | 2.10 | 15.70 | 14.39 |
| Rice husk | 1.12 | 0.97 | 18.24 | 19.55 | 2.42 | 1.92 | 3.83 | 3.02 | 2.50 | 1.82 | 11.46 | 16.25 |
| CD (0.05) | 0.16 | | 1.38 | | 0.45 | | 0.52 | | 0.41 | | 3.39 | |

increased the shoot:root ratio at harvest and the respective percentages were 20.6, 21.0, 27.0 and 41.8 per cent.

Fine silica on the other hand increased shoot weight at maximum tillering and flowering by 18.6 and 13.3 per cent respectively. Shoot:root ratio was increased at maximum tillering when combined with higher level of K but the effect did not persist even up to panicle initiation.

4.1.1.4 Three factor interaction effect of sources and levels of silica and K (Table 9)

Data on the combined effect of sources and levels of silica and K showed that the effect was significant in respect of shoot weight at flowering for sodium silicate and the decrease in shoot weight was to the tune of 14.2 per cent at lower level of K.

In case of fine silica, higher level of K increased the shoot weight at maximum tillering at 250 kg Si $ha^{-1}$ and shoot:root ratio at flowering at 500 kg Si $ha^{-1}$ and the increases were 24.3 and 36.3 per cent respectively.

In respect of rice husk, no significant combined effect was noted in respect of growth attributes.

4.1.2 Effects of treatments on yield and yield attributes (Table 10)

The treatments had significant effect in increasing the yield of rice. A mean increase of 1038 kg $ha^{-1}$ amounting to 19.5 per cent increase was recorded due to the treatment effect. Significant increases in 1000 grain weight, panicle weight and straw yield were also obtained due to the treatment effect. But the treatments had no significant effect on days to 50 per cent flowering, flag leaf length and width.

**Table 9.Three factor interaction effects on growth attributes**

| Treatments | Root wt at MT (g/ plant) | | Shoot wt at Flg (g/ plant) | | S/R at MT | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 0.41 | 0.37 | 21.8 | 18.7 | 2.25 | 2.97 |
| Sodium silicate Si500 | 0.27 | 0.36 | 21.1 | 20.9 | 3.01 | 2.66 |
| Fine silica Si250 | 0.25 | 0.25 | 13.6 | 16.9 | 3.16 | 3.72 |
| Fine silica Si500 | 0.34 | 0.30 | 18.8 | 19.8 | 2.73 | 3.72 |
| Rice husk Si250 | 0.24 | 0.34 | 17.0 | 18.3 | 4.55 | 2.84 |
| Rice husk Si500 | 0.39 | 0.31 | 19.7 | 20.8 | 3.11 | 3.20 |
| CD (0.05) | 0.11 | | 2.0 | | 0.73 | |

*a. Sources of silica*

Among the sources of silica tried, sodium silicate registered significantly higher panicle weight, number of grains, 1000 grain weight and straw yield. The percentage increases over rice husk, were worked out to 7.3, 5.4, 1.2 and 14.4 per cent. Between fine silica and rice husk, fine silica was significantly superior to rice husk in influencing panicle weight, filled grains, straw yield and grain:straw ratio.

Application of sodium silicate gave the highest grain yield of 6644 and straw 4128 kg $ha^{-1}$ followed by fine silica (6282 and 3607 kg $ha^{-1}$). Both these treatments were superior to rice husk.

*b. Levels of silica*

Application of 500 kg Si $ha^{-1}$ significantly increased the grain yield, straw yield, panicle weight, grain number per panicle and 1000 grain weight. The grain and straw yield increase was to the tune of 10.5 and 6.9 per cent, respectively.

*c. Levels of K*

Application of K at 70 kg $ha^{-1}$ increased appreciably the panicle weight, 1000 grain weight and grain yield.

4.1.2.1 Two factor interaction effect on yield and yield attributes (Table 11)

*Interaction effect between sources and levels of silica*

A perusal of the interaction effects between sources and levels of silica showed that except in the case of panicle length increasing level of silica irrespective of sources, increased the yield attributes though the magnitude of effects varied with different attributes. However increasing the level of application of sodium silicate from 250 to 500 kg $ha^{-1}$ decreased the panicle length whereas the other sources increased the same.

**Table 10. Effects of treatments on yield and yield attributes of rice**

| Treatments | Days to 50% flowering | Flag leaf width (cm) | Flag leaf length (cm) | Panicle length (cm) | Panicle weight (g) | Filled grains per panicle (No.) | Chaff percent | 1000 grain wt(g) | Grain :yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Grain straw ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 90.0 | 0.98 | 27.56 | 23.67 | 2.53 | 94.7 | 13.3 | 28.14 | 5308 | 3944 | 1.35 |
| Rest | 89.5 | 1.04 | 28.19 | 22.83 | 3.04 | 100.0 | 14.3 | 28.84 | 6346 | 3815 | 1.67 |
| CD (0.05) | NS | NS | NS | NS | 0.16 | NS | NS | 0.20 | 160 | 88 | 0.11 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 89.6 | 1.05 | 28.51 | 22.74 | 3.23 | 105.3 | 15.8 | 28.95 | 6644 | 4128 | 1.61 |
| Fine silica | 90.5 | 1.03 | 27.49 | 23.00 | 3.01 | 99.9 | 13.3 | 28.62 | 6282 | 3607 | 1.75 |
| Rice husk | 88.3 | 1.05 | 28.56 | 23.08 | 2.87 | 94.8 | 13.7 | 28.94 | 6113 | 3110 | 1.65 |
| CD (0.05) | 1.1 | NS | NS | NS | 0.11 | 3.7 | 1.8 | 0.14 | 109 | 60 | 0.07 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 89.3 | 1.03 | 27.92 | 23.05 | 2.78 | 96.7 | 14.1 | 28.41 | 6030 | 3687 | 1.64 |
| $Si_{500}$ | 89.7 | 1.06 | 28.46 | 22.08 | 3.29 | 103.3 | 14.5 | 29.26 | 6662 | 3943 | 1.70 |
| CD (0.05) | NS | NS | NS | NS | 0.09 | 3.0 | NS | 0.11 | 89 | 49 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 89.6 | 1.04 | 27.78 | 23.07 | 2.93 | 98.0 | 14.1 | 28.70 | 6259 | 3801 | 1.65 |
| $K_{70}$ | 89.4 | 1.05 | 28.6 | 22.82 | 3.14 | 101.9 | 14.4 | 28.98 | 6433 | 3829 | 1.69 |
| CD (0.05) | NS | NS | NS | NS | 0.09 | NS | NS | 0.11 | 89 | NS | NS |

Sodium silicate applied at 500 kg $ha^{-1}$ had recorded significantly higher panicle weight, number of filled grains per panicle and 1000 grain weight.

The best grain:straw ratio was recorded by fine silica at 500 kg $ha^{-1}$. It may also be seen that sodium silicate had given the lowest grain:straw ratio of 1.58 at 250 kg $ha^{-1}$ which was significantly inferior to rice husk at 250 kg $ha^{-1}$.

*Interaction effect between levels of K and sources of silica*

Sodium silicate and rice husk application increased 1000 grain weight significantly in the presence of higher level of K, while fine silica did not manifest any combined effect. However in the case of straw yield, combined effect had brought about significant increase at higher level of K in the case of sodium silicate whereas the effect was not apparent in the case of the other two sources.

Interaction effect between levels of silica and K

Data on the combined effect showed that higher level of silica had significantly increased the 1000 grain weight when K level was raised to 70 kg $ha^{-1}$.

4.1.2.2 Three factor interaction effects of sources and levels of silica and K levels (Table 12)

Significant additive effect varying in magnitude with sources was observed through combining sources and levels of silica with the levels of K.

Highest grain yield of 7306 kg $ha^{-1}$ was recorded by the combined effect of 70 kg K $ha^{-1}$ and 500 kg Si $ha^{-1}$ as sodium silicate followed by 6741 kg $ha^{-1}$ recorded by the combination of 52.5 kg K $ha^{-1}$ and 250 kg Si $ha^{-1}$ as sodium silicate. The effect of K was enhanced in the presence of sodium silicate applied at the rate of 500 kg Si $ha^{-1}$.

**Table 11.Two factor interaction effects on yield and yield attributes**

| Treatments | Panicle length (cm) | | Panicle weight (g) | | Filled grains per panicle (No.) | | Chaff per panicle (No.) | | 1000 grain wt(g) | | Straw yield (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 23.4 | 22.1 | 3.02 | 3.45 | 98.0 | 112.5 | 17.3 | 14.5 | 28.38 | 29.52 | 3960 | 4296 |
| Fine silica | 22.7 | 23.3 | 2.80 | 3.22 | 96.8 | 103.0 | 12.3 | 14.3 | 28.42 | 28.86 | 3677 | 3537 |
| Rice husk | 22.9 | 23.1 | 2.52 | 3.20 | 95.2 | 103.3 | 12.5 | 14.8 | 28.48 | 29.41 | 3425 | 3996 |
| CD (0.05) | 0.8 | | 0.16 | | 5.2 | | 2.5 | | 0.19 | | 85 | |

| Treatments | Grain :straw ratio | | Days to50% flowering | |
|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.58 | 1.64 | 88.7 | 90.7 |
| Fine silica | 1.64 | 1.85 | 90.5 | 90.3 |
| Rice husk | 1.69 | 1.61 | 88.5 | 88.2 |
| CD (0.05) | 0.10 | | 1.6 | |

| Treatments | 1000 grain wt(g) | | Straw yield (kg $ha^{-1}$) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 28.76 | 29.15 | 4045 | 4211 |
| Fine silica | 28.61 | 28.64 | 3632 | 3582 |
| Rice husk | 28.74 | 29.15 | 3727 | 3693 |
| CD (0.05) | 0.19 | | 85 | |

| Treatments | 1000 grain wt(g) | |
|---|---|---|
| | K52.5 | K70.0 |
| Si250 | 28.38 | 28.42 |
| Si500 | 28.99 | 29.54 |
| CD (0.05) | 0.16 | |

**Table 12.Three factor interaction effects on yield and yield attributes**

| Treatments | Panicle length (cm) | | Panicle weight (g) | | Chaff per panicle (No.) | | Grain yield (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 24.2 | 22.9 | 3.0 | 3.0 | 17.7 | 17.0 | 6240 | 6290 |
| Sodium silicate Si500 | 21.7 | 22.5 | 3.2 | 3.7 | 14.0 | 14.7 | 6741 | 7306 |
| Fine silica Si250 | 22.3 | 23.2 | 2.6 | 3.0 | 12.0 | 12.7 | 5972 | 6094 |
| Fine silica Si500 | 23.8 | 22.8 | 3.2 | 3.3 | 15.0 | 13.7 | 6484 | 6577 |
| Rice husk Si250 | 23.1 | 23.0 | 2.3 | 2.7 | 14.0 | 11.0 | 5763 | 5823 |
| Rice husk Si500 | 23.3 | 22.8 | 3.3 | 3.2 | 12.0 | 17.7 | 6356 | 6507 |
| CD (0.05) | 1.2 | | 0.2 | | 1.7 | | 217 | |

4.1.3 Effects of treatments on nutrient content and uptake at maximum tillering

4.1.3.1 Effects of treatments on nutrient content (Table 13)

Treatment effects significantly increased the N, P, Na and $SiO_2$ contents by 10.3, 5.9, 59.2 and 22.9 per cent over control. K, S, Mn and Zn content were not significantly affected. Ca, Mg and Fe contents decreased by 35.9, 4.6 and 23.9 per cent respectively.

*a. Sources of silica*

Sources of silica varied in their effect on nutrient content of the rice at maximum tillering stage. Sodium silicate recorded the highest content of P, Na and Fe and the lowest content of K, Ca, Mg, Mn and Zn and the differences with other sources were statistically significant.

Rice husk gave the highest N, K, Mn and Zn content while fine silica recorded the highest content of Ca, Mg, S and they were significantly different from other sources.

*b. Levels of silica*

Increasing the level of application of silica from 250 to 500 kg $ha^{-1}$ significantly increased the N, Mg and Fe contents by 5.2, 4.1 and 16.9 per cent over the lower level and decreased P, K and Ca by 3.1, 4.4 and 13.3 per cent respectively. Other elements remained unaffected.

*c. Levels of K*

Enhancement in the level of application of K to 70 kg $ha^{-1}$ increased N, S and Zn contents by 13.0, 15.3 and 9.7 per cent respectively and decreased the silica content by 16.8 per cent.

**Table 13. Effects of treatments on nutrient content of rice at maximum tillering**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 2.52 | 0.393 | 3.17 | 0.142 | 0.132 | 4009 | 0.62 | 5644 | 151 | 33 | 2.45 |
| Rest | 2.78 | 0.416 | 3.15 | 0.091 | 0.126 | 4032 | 0.99 | 4298 | 142 | 33 | 3.01 |
| CD (0.05) | 0.17 | 0.021 | NS | 0.019 | 0.005 | NS | 0.12 | 494 | NS | NS | 0.22 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 2.77 | 0.433 | 2.92 | 0.066 | 0.119 | 3982 | 1.78 | 4364 | 123 | 31 | 2.83 |
| Fine silica | 2.74 | 0.407 | 3.23 | 0.108 | 0.132 | 4284 | 0.61 | 4292 | 150 | 33 | 3.12 |
| Rice husk | 2.84 | 0.409 | 3.30 | 0.100 | 0.126 | 3831 | 0.58 | 4238 | 153 | 34 | 3.07 |
| CD (0.05) | NS | 0.014 | 0.11 | 0.013 | 0.004 | NS | 0.08 | NS | 11 | 2.0 | 0.15 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 2.71 | 0.423 | 3.22 | 0.098 | 0.123 | 4179 | 0.99 | 3963 | 141 | 33 | 2.99 |
| $Si_{500}$ | 2.85 | 0.410 | 3.08 | 0.085 | 0.128 | 3885 | 0.99 | 4633 | 142 | 32 | 3.02 |
| CD (0.05) | 0.09 | 0.012 | 0.09 | 0.011 | 0.003 | NS | NS | 274 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 2.61 | 0.411 | 3.14 | 0.093 | 0.125 | 3745 | 0.98 | 4278 | 141 | 31 | 3.28 |
| $K_{70}$ | 2.95 | 0.421 | 3.16 | 0.090 | 0.126 | 4319 | 1.00 | 4318 | 143 | 34 | 2.73 |
| CD (0.05) | 0.09 | 0.012 | NS | NS | NS | 388 | NS | NS | NS | 2.0 | 0.12 |

4.1.3.2 Effects of treatments on nutrient uptake (Table 14)

A perusal of the data showed that the applied treatments significantly increased the Na and $SiO_2$ content and reduced the Ca and Fe content by 49.7, 16.7, 39.2 and 28.2 per cent respectively.

*a. Sources of silica*

The different sources of applied silica significantly affected P, Ca, Na and $SiO_2$ uptake. Sodium silicate recorded the highest uptake of P and Na and lowest uptake of Ca and $SiO_2$. Among fine silica and rice husk, rice husk had the maximum uptake of P, Ca, Na, Mn and $SiO_2$.

*b. Levels of silica*

Effect of increase in the level of silica was confined only to Fe and $SiO_2$ uptake and the increase was to the tune of 18.2 and 3.8 per cent respectively.

*c. Levels of K*

Application of 70 kg K $ha^{-1}$ increased the N, P, Zn and reduced the $SiO_2$ content by 20.0, 8.9, 15.4 and 11.9 per cent respectively.

4.1.3.3 Two factor interaction effects on nutrient content and uptake at maximum tillering (Table 15)

*Interaction effect between sources and levels of silica*

*a. Nutrient content*

Increasing the level of sodium silicate from 250 to 500 kg $ha^{-1}$ increased the Fe content by 33.3 per cent and decreased the K, Ca and Zn contents by 10.0, 25.8 and 9.4 per cent. As against this, fine silica increased the Ca, Fe and Mn contents by 20.0, 30.2 and 16.7 per cent. Rice husk decreased only the P content significantly.

**Table 14. Effects of Treatments on nutrient uptake (kg ha$^{-1}$) of rice at maximum tillering**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 23.15 | 3.59 | 29.0 | 1.30 | 1.21 | 3.72 | 5.71 | 5.17 | 0.139 | 0.030 | 22.30 |
| Rest | 24.29 | 3.63 | 27.6 | 0.79 | 1.09 | 3.55 | 8.55 | 3.72 | 0.123 | 0.028 | 26.03 |
| CD (0.05) | NS | NS | NS | 0.23 | NS | NS | 1.30 | 0.62 | NS | NS | 1.53 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 24.42 | 3.81 | 25.7 | 0.58 | 1.04 | 3.54 | 15.62 | 3.78 | 0.107 | 0.027 | 24.50 |
| Fine silica | 22.57 | 3.34 | 26.6 | 0.88 | 1.09 | 3.53 | 5.03 | 3.56 | 0.124 | 0.028 | 25.44 |
| Rice husk | 25.89 | 3.73 | 30.5 | 0.92 | 1.16 | 3.58 | 5.27 | 3.81 | 0.139 | 0.031 | 28.16 |
| CD (0.05) | NS | 0.37 | NS | 0.16 | NS | NS | 0.88 | NS | 0.017 | NS | 1.04 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 23.51 | 3.65 | 27.7 | 0.82 | 1.06 | 3.60 | 8.89 | 3.41 | 0.121 | 0.028 | 25.55 |
| $Si_{500}$ | 25.08 | 3.60 | 27.5 | 0.76 | 1.13 | 3.50 | 8.39 | 4.03 | 0.125 | 0.029 | 26.52 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | 0.42 | NS | NS | 0.85 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 22.09 | 3.47 | 26.9 | 0.79 | 1.06 | 3.22 | 8.12 | 3.56 | 0.120 | 0.026 | 27.68 |
| $K_{70}$ | 26.50 | 3.78 | 28.3 | 0.80 | 1.12 | 3.88 | 9.16 | 3.87 | 0.127 | 0.030 | 24.39 |
| CD (0.05) | 4.22 | 0.30 | NS | NS | NS | NS | 0.72 | NS | NS | 0.003 | 0.85 |

**Table 15. Two factor interaction effects on nutrient content and uptake of rice at maximum tillering**

| Treatments | P (%) | | K (%) | | Ca (%) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.433 | 0.435 | 3.08 | 2.77 | 0.031 | 0.023 | 3741 | 4988 | 128 | 118 | 32 | 29 |
| Fine silica | 0.408 | 0.406 | 3.28 | 3.18 | 0.025 | 0.030 | 3729 | 4855 | 138 | 161 | 33 | 34 |
| Rice husk | 0.428 | 0.390 | 3.31 | 3.29 | 0.029 | 0.032 | 4420 | 4056 | 158 | 147 | 33 | 35 |
| CD (0.05) | 0.021 | | 0.16 | | 0.004 | | 475 | | 16 | | 2.9 | |

| Treatments | N uptake (kg $ha^{-1}$) | | P uptake (kg $ha^{-1}$) | | K uptake (kg $ha^{-1}$) | | Na uptake (kg $ha^{-1}$) | | Fe uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | | $SiO_2$ uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 26.1 | 22.7 | 4.1 | 3.5 | 29.1 | 22.3 | 17.0 | 14.2 | 3.6 | 4.0 | 0.121 | 0.094 | 25.7 | 23.3 |
| Fine silica | 19.7 | 25.5 | 3.0 | 3.6 | 24.7 | 28.5 | 4.3 | 5.8 | 2.8 | 4.3 | 0.104 | 0.145 | 23.1 | 27.7 |
| Rice husk | 24.7 | 27.0 | 3.8 | 3.7 | 29.3 | 31.8 | 5.4 | 5.2 | 3.9 | 3.7 | 0.139 | 0.138 | 27.8 | 28.5 |
| CD (0.05) | 4.2 | | 0.5 | | 6.1 | | 1.2 | | 0.6 | | 0.024 | | 1.5 | |

| Treatments | N (%) | | P (%) | | S (ppm) | | Na (%) | | Mg (%) | | Mn (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 2.51 | 3.03 | 0.413 | 0.453 | 3405 | 4558 | 1.71 | 1.84 | 0.125 | 0.114 | 136 | 110 | 32 | 30 |
| Fine silica | 2.64 | 2.84 | 0.400 | 0.414 | 4310 | 4257 | 0.67 | 0.56 | 0.129 | 0.135 | 142 | 157 | 31 | 36 |
| Rice husk | 2.70 | 2.99 | 0.420 | 0.403 | 3520 | 4141 | 0.57 | 0.60 | 0.122 | 0.129 | 144 | 161 | 32 | 36 |
| CD (0.05) | 0.16 | | 0.021 | | 709 | | 0.11 | | 0.005 | | 16 | | 2.9 | |

*b. Nutrient uptake*

Sodium silicate at 500 kg significantly reduced the uptake of P, K, Na, Mn and $SiO_2$ at maximum tillering stage by 14.6, 23.4, 16.5, 22.3 and 9.3 over 250 kg $ha^{-1}$ level. Fine silica increased the uptake of N, P, Na, Fe, Mn and $SiO_2$ by 29.4, 20.0, 34.9, 53.6, 39.4 and 19.9 per cent over the lower level. Levels of rice husk did not influence the uptake at maximum tillering stage of any element significantly.

*Interaction effect between sources of silica and levels of K*

*a. Nutrient content*

Sodium silicate application in the presence of higher level of K (70 kg $ha^{-1}$) increased the N, P, S and Na contents by 20.7, 9.7, 33.9 and 7.6 per cent and decreased Mg and Mn contents by 8.8 and 19.0 per cent respectively over the lower level of K (52.5 kg $ha^{-1}$). Fine silica increased N, Mg, and Zn content by 7.6, 4.7, and 16.1 per cent and decreased Na by 16.4 per cent. Rice husk also increased N, Mg, Mn and Zn by 10.7, 5.7, 11.8 and 12.5 per cent over the lower level.

*b. Nutrient uptake*

Interaction effect between sources of silica and levels of K showed that irrespective of the sources, uptake of $SiO_2$ was decreased at maximum tillering increased level of K. However, the source variation in silica was apparent in their effect on uptake of N, P and Na. Sodium silicate increased N, P and Na uptake in the presence of the higher level of K, by 44.0, 30.3 and 25.2 per cent. Fine silica significantly increased the N, P uptake by 23.5 and 16.1 per cent while rice husk did not affect any of the elements.

*Interaction effect between levels of silica and K on content of N and $SiO_2$ and uptake of Na and $SiO_2$*

A perusal of the data showed that the effect of silica in increasing the N content of plant at maximum tillering was significantly affected by level of K. At

**Table 15. Continued...**

| Treatments | N uptake (kg ha$^{-1}$) | | P uptake (kg ha$^{-1}$) | | Na uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 20.0 | 28.8 | 3.3 | 4.3 | 13.9 | 17.4 | 25.0 | 24.0 |
| Fine silica | 20.5 | 24.7 | 3.1 | 3.6 | 5.2 | 4.9 | 26.7 | 24.2 |
| Rice husk | 25.8 | 26.0 | 4.0 | 3.5 | 5.3 | 5.2 | 31.3 | 25.0 |
| CD (0.05) | 4.2 | | 0.5 | | 1.2 | | 1.5 | |

| Treatments | N (%) | | $SiO_2$ (%) | | Na uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 2.47 | 2.96 | 3.17 | 2.80 | 8.78 | 9.00 | 26.30 | 24.81 |
| Si500 | 2.75 | 2.95 | 3.39 | 2.66 | 7.45 | 9.33 | 29.06 | 23.97 |
| CD (0.05) | 0.13 | | 0.17 | | 1.02 | | 1.20 | |

52.5 kg ha$^{-1}$ increasing the level of silica from 250 to 500 kg ha$^{-1}$ increased the N content by 11.3 per cent. At 70 kg ha$^{-1}$ level increment in silica level was found to have no effect. However at the same level of silica, increasing levels of K had increased the N content and the increases were 19.8 and 7.2 at 250 and 500 kg ha$^{-1}$ levels of silica.

4.1.3.4 Three factor interaction effect among sources and levels of silica and K levels (Table 16)

Data on three factor interaction among sources and levels of silica and K levels showed significant variation in the contents of applied as well as native elements. Increasing levels of sodium silicate in the presence of lower dose of 52.5 kg ha$^{-1}$ increased the plant content of N and Mg but failed to register any influence on the plant content of these elements at higher level of 70 kg ha$^{-1}$. Fine silica behaved similarly only in respect of increase in the N content (11.3 per cent). Rice husk did not manifest any interaction with K in the case of N and Mg. In the case of P and Fe at higher level of K sodium silicate and fine silica exerted no effect while rice husk had reduced the P content significantly by 11.6 per cent.

4.1.4 Effects of treatments on nutrient content and uptake at panicle initiation

4.1.4.1 Effects of treatments on nutrient content (Table 17)

Compared to control, the general treatment effect on elemental composition of the plant had been to reduce the contents of P, Mg, Mn, Fe, and $SiO_2$ and the percentage reduction was worked out to 6.1, 6.0, 24.4, 13.2 and 26.5 per cent Na alone showed an increase of 32.9 per cent. N, K, $SiO_2$ and Zn were not affected at all.

*a. Sources of silica*

A comparison of the effect of sources of silica on the elemental composition of the plant at panicle initiation stage showed that sodium silicate

**Table 16. Three factor interaction effects on nutrient content of rice at maximum tillering**

| Treatments | N (%) | | P (%) | | Mg (%) | | Fe (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 2.22 | 3.24 | 0.410 | 0.455 | 0.117 | 0.113 | 3377 | 4104 |
| Sodium silicate Si500 | 2.80 | 2.82 | 0.417 | 0.450 | 0.133 | 0.114 | 5270 | 4705 |
| Fine silica Si250 | 2.47 | 2.75 | 0.410 | 0.407 | 0.132 | 0.129 | 4056 | 3402 |
| Fine silica Si500 | 2.80 | 2.92 | 0.389 | 0.422 | 0.126 | 0.140 | 4808 | 4902 |
| Rice husk Si250 | 2.73 | 2.87 | 0.426 | 0.429 | 0.121 | 0.128 | 4622 | 4222 |
| Rice husk Si500 | 2.66 | 3.10 | 0.414 | 0.366 | 0.124 | 0.131 | 3536 | 4577 |
| CD (0.05) | 0.23 | | 0.029 | | 0.007 | | 671 | |

**Table 17. Effects of treatments on nutrient content of rice at panicle initiation**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 2.45 | 0.424 | 3.07 | 0.136 | 0.134 | 4007 | 0.70 | 6451 | 164 | 33.3 | 3.58 |
| Rest | 2.51 | 0.398 | 3.10 | 0.136 | 0.126 | 3371 | 0.93 | 5597 | 124 | 34.1 | 2.63 |
| CD (0.05) | NS | 0.020 | NS | NS | 0.006 | NS | 0.15 | 506 | 14.8 | NS | 0.26 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 2.46 | 0.398 | 2.87 | 0.118 | 0.122 | 3539 | 1.46 | 119 | 5033 | 33.5 | 1.88 |
| Fine silica | 2.55 | 0.395 | 3.15 | 0.151 | 0.130 | 3247 | 0.71 | 5954 | 132 | 35.8 | 2.84 |
| Rice husk | 2.51 | 0.401 | 3.26 | 0.138 | 0.127 | 3327 | 0.61 | 5804 | 120 | 33.1 | 3.16 |
| CD (0.05) | NS | NS | 0.14 | 0.004 | 0.004 | NS | 0.10 | 344 | 10.1 | 2.2 | 0.18 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 2.42 | 0.392 | 3.08 | 0.136 | 0.127 | 3358 | 0.85 | 5286 | 124 | 36.1 | 2.67 |
| $Si_{500}$ | 2.60 | 0.404 | 3.11 | 0.135 | 0.126 | 3384 | 1.01 | 5908 | 123 | 32.1 | 2.58 |
| CD (0.05) | 0.07 | 0.011 | NS | NS | NS | NS | 0.08 | 281 | NS | 1.8 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 2.49 | 0.397 | 3.12 | 0.134 | 0.125 | 3496 | 0.94 | 5802 | 125 | 34.5 | 2.60 |
| $K_{70}$ | 2.53 | 0.399 | 3.08 | 0.137 | 0.128 | 3246 | 0.92 | 5392 | 123 | 33.7 | 2.65 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | 281 | NS | NS | NS |

recorded significantly lower content of K, Ca, Mg, Mn and Fe, compared to other sources. Sources did not differ significantly in affecting the N, P and S contents.

*b. Levels of silica*

Increasing the level of silica application from 250 to 500 kg $ha^{-1}$ increased the N, P, Na and Fe contents by 7.4, 3.1, 18.8 and 11.8 per cent and reduced the Zn content by 11.1 per cent. Levels of silica did not affect K, Ca, Mg, S, Mn and $SiO_2$.

*c. Levels of K*

Effect of increasing the level of application of K from 52.5 to 70 kg $ha^{-1}$ was confined to Fe, which got reduced from 5802 to 5392 ppm.

4.1.4.2 Effects of treatments on uptake of nutrients (Table 18)

Data on the total nutrients taken up by the plant upto panicle initiation stage showed that the overall treatment effect had been confined only to Na and $SiO_2$. Treatment effect increased the Na uptake by 34.6 per cent but reduced $SiO_2$ uptake by 21.0 per cent.

*a. Sources of Silica*

A scrutiny of the data on the effect of sources of silica revealed that sodium silicate recorded significantly lower uptake in respect of all elements except Na and the rice husk had the highest uptake and the decreases due to sodium silicate worked out to 22.5, 20.9, 29.3, 32.9, 22.9, 28.2, 18.3 and 52.3 per cent over that of rice husk in respect of N, P, K, Ca, Mg, Fe, Mn and $SiO_2$ respectively. However sodium silicate gave the highest uptake of 21 kg Na $ha^{-1}$ which was 44.8 per cent more than that of rice husk. Uptake figures for fine silica was in between the other two sources.

**Table 18. Effects of Treatments on nutrient uptake (kg ha$^{-1}$) of rice at panicle initiation**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 37.61 | 6.55 | 46.95 | 2.08 | 2.06 | 6.22 | 10.82 | 9.91 | 0.252 | 0.052 | 55.36 |
| Rest | 40.97 | 6.51 | 50.84 | 2.24 | 2.07 | 5.42 | 14.56 | 9.19 | 0.204 | 0.056 | 43.67 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 3.50 | NS | NS | NS | 11.18 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 35.58 | 5.79 | 41.99 | 1.75 | 1.78 | 5.04 | 21.00 | 7.48 | 0.179 | 0.050 | 27.44 |
| Fine silica | 41.42 | 6.41 | 51.15 | 2.45 | 2.11 | 5.24 | 11.59 | 9.70 | 0.214 | 0.057 | 46.12 |
| Rice husk | 45.90 | 7.32 | 59.37 | 2.51 | 2.31 | 5.98 | 11.07 | 10.41 | 0.219 | 0.061 | 57.46 |
| CD (0.05) | 6.01 | 0.94 | 7.58 | 0.32 | 0.27 | NS | 2.38 | 1.36 | 0.03 | NS | 7.60 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 42.27 | 6.87 | 54.06 | 2.37 | 2.20 | 5.83 | 14.98 | 9.21 | 0.217 | 0.063 | 46.54 |
| $Si_{500}$ | 39.67 | 6.14 | 47.61 | 2.10 | 1.93 | 5.01 | 14.14 | 9.18 | 0.191 | 0.049 | 40.81 |
| CD (0.05) | NS | NS | 6.19 | 0.26 | 0.22 | NS | NS | NS | NS | 0.07 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 37.74 | 6.02 | 47.24 | 2.06 | 1.90 | 5.26 | 13.92 | 8.89 | 0.193 | 0.052 | 39.94 |
| $K_{70}$ | 44.19 | 7.00 | 54.43 | 2.42 | 2.23 | 5.58 | 15.19 | 9.49 | 0.214 | 0.059 | 47.40 |
| CD (0.05) | 4.91 | 0.76 | 6.19 | 0.26 | 0.22 | NS | NS | NS | NS | NS | 6.20 |

*b. Levels of silica*

Increasing the level of application of silica from 250 kg to 500 kg $ha^{-1}$ reduced the uptake of K, Ca, Mg and Zn by 16.6, 11.4, 12.3 and 22.2 per cent respectively. N, P, S, Na, Fe, Mn and $SiO_2$ remained unaffected.

*c. Levels of K*

It may further be observed from the table that increasing the level of K application from 52.5 to 70 kg $ha^{-1}$ significantly increased the uptake of N, P, K, Ca, Mg and $SiO_2$ by 17.1, 16.3, 15.3, 17.5, 17.4 and 18.7 per cent respectively.

4.1.4.3 Two factor interaction effects on nutrient content and uptake at panicle initiation (Table 19)

*Interaction effect between sources and levels of silica*

*a. Nutrient content*

The perusal of data showed that increasing levels of silica as sodium silicate increased the S content and reduced the Mn content by 29.1 and 11.8 per cent respectively. But fine silica increased the Ca and Fe content and reduced Zn content by 6.1, 18.6 and 19.0 per cent at the higher level of silica. Effect of rice husk was confined to Ca, Fe and $SiO_2$ content only.

*b. Nutrient uptake*

Data showed that application of sodium silicate at 500 kg $ha^{-1}$ reduced the uptake of N, P, K, Ca, Mg, Fe and Mn by 32.9, 34.3, 39.6, 40.9, 36.4, 43.8 and 47.8 per cent. But fine silica at higher level increased only the Fe uptake by 25.6 per cent. Rice husk showed no significant interaction effect on the nutrient uptake.

*Interaction effect between sources of silica and levels of K on nutrient content and uptake*

Application of silica as sodium silicate with increasing levels of K increased Ca and $SiO_2$ content by 12.6 and 16.1 per cent. In respect of nutrient

**Table 19. Two factor interaction effects on nutrient content and uptake of rice at panicle initiation**

| Treatments | P (%) | | Ca (%) | | S (ppm) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.381 | 0.412 | 0.121 | 0.116 | 3089 | 3988 | 5229 | 4838 | 127 | 112 | 34.3 | 32.7 | 1.80 | 1.95 |
| Fine silica | 0.399 | 0.392 | 0.147 | 0.156 | 3491 | 3002 | 5448 | 6460 | 131 | 132 | 39.5 | 32.0 | 2.91 | 2.78 |
| Rice husk | 0.397 | 0.405 | 0.142 | 0.134 | 3494 | 3161 | 5181 | 6428 | 115 | 126 | 34.5 | 31.7 | 3.31 | 3.01 |
| CD (0.05) | 0.131 | | 0.006 | | 714 | | 487 | | 14 | | 3.0 | | 0.25 | |

| Treatments | N uptake (kg $ha^{-1}$) | | P uptake (kg $ha^{-1}$) | | K uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | Mg uptake (kg $ha^{-1}$) | | Fe uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 42.6 | 28.6 | 7.0 | 4.6 | 52.3 | 31.6 | 2.2 | 1.3 | 2.2 | 1.4 | 9.6 | 5.4 | 0.23 | 0.12 |
| Fine silica | 39.2 | 43.7 | 6.3 | 6.6 | 48.4 | 53.9 | 2.3 | 2.6 | 2.1 | 2.2 | 8.6 | 10.8 | 0.21 | 0.22 |
| Rice husk | 45.0 | 46.8 | 7.4 | 7.3 | 61.4 | 57.3 | 2.6 | 2.4 | 2.4 | 2.3 | 9.5 | 11.3 | 0.21 | 0.23 |
| CD (0.05) | 8.5 | | 1.3 | | 10.7 | | 0.5 | | 0.4 | | 2.0 | | 0.05 | |

| Treatments | N (%) | | Ca (%) | | $SiO_2$ (%) | | N uptake (kg $ha^{-1}$) | | P uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | Mg uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 2.42 | 2.50 | 0.111 | 0.125 | 1.74 | 2.02 | 34.7 | 36.5 | 5.7 | 5.8 | 1.65 | 1.85 | 1.74 | 1.83 |
| Fine silica | 2.60 | 2.51 | 0.155 | 0.147 | 2.80 | 2.88 | 40.8 | 42.0 | 6.3 | 6.6 | 2.43 | 2.47 | 2.02 | 2.20 |
| Rice husk | 2.46 | 2.57 | 0.136 | 0.139 | 3.27 | 3.05 | 37.7 | 54.1 | 6.1 | 8.6 | 2.08 | 2.94 | 1.94 | 2.67 |
| CD (0.05) | 0.12 | | 0.006 | | 0.25 | | 8.5 | | 1.3 | | 0.45 | | 0.39 | |

uptake, only rice husk had significant effect wherein increasing levels of K increased the N, Ca, Mg and Mn uptake by 43.5, 41.0, 41.3, 37.6 and 38.0 per cent.

*Interaction effect between levels of silica and K on nutrient content and uptake*

Data showed that application of 250kg Si $ha^{-1}$ with increasing levels of K decreased the Ca, Mg, Fe and Mn content at panicle initiation stage by 3.6, 4.6, 17.1 and 15.6 per cent. But application of 500kg Si $ha^{-1}$ with increasing levels of K increased the Ca, Mg and Mn content by 7.7, 9.1 and 13.9 per cent. Enhancement of silica from 250 to 500 kg $ha^{-1}$, at 52.5 kg K decreased Ca, Mg and Mn content by 6.5, 6.9 and 14.8 per cent. However increasing levels of silica at 70 kg K increased Ca, Mg, Fe, and Mn by 4.5, 6.5, 25.1 and 14.9 per cent. Application of 500 kg Si $ha^{-1}$ with different levels of K significantly increased the Fe and Mn uptake.

4.1.4.4 Three factor interaction effects of sources and levels of silica and levels of K on nutrient content and uptake (Table 20)

Data on combined effect showed that the effect of application of higher level of sodium silicate with increasing levels of K was confined to Ca and $SiO_2$ content. At 250 kg Si $ha^{-1}$, application of fine silica with increasing levels of K decreased Fe content by 32.7 per cent but increasing level of silica to 500 kg increased the Fe content by 22.7 per cent and decreased the N content by 9.1 per cent. Rice husk at 500 kg Si $ha^{-1}$ with different levels of K increased N and Ca content and reduced the Fe content by 7.2, 15.3 and 15.6 per cent respectively.

Increasing the levels of sodium silicate at 52.5 and 70 kg K $ha^{-1}$ level decreased Fe uptake by 56.3 and 29.7 per cent. Application of 250 kg Si as fine silica with two levels of K decreased the Fe uptake by 31.2, but at 500 kg $ha^{-1}$ level increased the Fe uptake by 38.4 per cent respectively. From the table it was apparent that there was no significant effect on Fe uptake by rice husk application.

**Table 19. continued...**

| Treatments | Mn uptake (kg $ha^{-1}$) | | Zn uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.195 | 0.163 | 0.050 | 0.049 |
| Fine silica | 0.202 | 0.226 | 0.058 | 0.057 |
| Rice husk | 0.184 | 0.254 | 0.050 | 0.072 |
| CD (0.05) | 0.050 | | 0.012 | |

| Treatments | K (%) | | Ca (%) | | Mg (%) | | Fe (ppm) | | Mn (ppm) | | Fe uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 3.04 | 3.12 | 0.139 | 0.134 | 0.130 | 0.124 | 5780 | 4792 | 135 | 114 | 9.58 | 8.84 | 0.23 | 0.21 |
| Si500 | 3.19 | 3.03 | 0.130 | 0.140 | 0.121 | 0.132 | 5824 | 5993 | 115 | 131 | 8.21 | 10.15 | 0.16 | 0.22 |
| CD (0.05) | 0.16 | | 0.005 | | 0.005 | | 397 | | 12 | | 1.57 | | 0.04 | |

**Table 20. Three factor interaction effects on nutrient content and uptake of rice at panicle initiation**

| Treatments | N (%) | | Ca (%) | | Fe (ppm) | | $SiO_2$ (%) | | Fe uptake(kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 2.31 | 2.37 | 0.118 | 0.123 | 5388 | 5070 | 1.88 | 1.73 | 10.48 | 8.72 |
| Sodium silicate Si500 | 2.52 | 2.64 | 0.105 | 0.126 | 4700 | 4976 | 1.59 | 2.30 | 4.58 | 6.13 |
| Fine silica Si250 | 2.45 | 2.52 | 0.150 | 0.143 | 6511 | 4384 | 2.86 | 2.97 | 10.14 | 6.98 |
| Fine silica Si500 | 2.75 | 2.50 | 0.160 | 0.152 | 5801 | 7119 | 2.75 | 2.80 | 9.09 | 12.58 |
| Rice husk Si250 | 2.43 | 2.45 | 0.148 | 0.136 | 5442 | 4921 | 3.38 | 3.23 | 8.13 | 10.82 |
| Rice husk Si500 | 2.50 | 2.68 | 0.124 | 0.143 | 6972 | 5883 | 3.17 | 2.86 | 10.95 | 11.72 |
| CD (0.05) | 0.17 | | 0.008 | | 688 | | 0.35 | | 2.71 | |

4.1.5 Effects of treatments on nutrient content and uptake at flowering

4.1.5.1 Effects of treatments on nutrient content (Table 21)

Data showed that the Ca and Fe contents were appreciably higher in control than the treatments. But P, K and Mg contents were significantly higher in treatments than the control and the increase was 9.9, 9.2 and 14.8 per cent respectively.

*a. Sources of silica*

Application of sodium silicate recorded higher content of Ca, Na and $SiO_2$ than the other two sources. Between rice husk and fine silica, $SiO_2$ content was increased by 8.8 per cent and Na content was reduced by 10.4 per cent in rice husk. But the sources did not differ significantly in respect of N, P, K, Mg, S and Mn contents.

*b. Levels of silica*

Application of higher level of silica significantly reduced the contents of N and Mn by 8.2 and 11.0 per cent but increased the contents of P, Fe and $SiO_2$ content by 5.0, 12.8 and 9.1 per cent.

*c. Levels of K*

Application of K at 70 kg $ha^{-1}$ increased the K content by 6.9 per cent but reduced the Fe, Ca and Mg content by 5.8, 3.2 and 4.0 per cent respectively.

4.1.5.2 Effects of treatments on nutrient uptake (Table 22)

The treatments applied significantly increased the uptake of all the elements except S.

*a. Source of silica*

A perusal of the data showed that the application of sodium silicate recorded the highest uptake of all the nutrients. The increases in uptake of N, P, K,

**Table 21. Effects of treatments on nutrient content of rice at flowering**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 1.61 | 0.243 | 1.52 | 0.162 | 0.108 | 1176 | 0.75 | 2184 | 220 | 42.3 | 4.95 |
| Rest | 1.52 | 0.267 | 1.66 | 0.153 | 0.124 | 992 | 0.76 | 1801 | 216 | 43.0 | 4.82 |
| CD (0.05) | NS | 0.018 | 0.14 | 0.006 | 0.008 | NS | NS | 161 | NS | NS | NS |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 1.50 | 0.264 | 1.68 | 0.158 | 0.126 | 1020 | 0.83 | 1804 | 216 | 40.6 | 5.41 |
| Fine silica | 1.57 | 0.268 | 1.62 | 0.149 | 0.122 | 923 | 0.77 | 1747 | 216 | 45.0 | 4.33 |
| Rice husk | 1.50 | 0.269 | 1.68 | 0.153 | 0.124 | 1032 | 0.69 | 1852 | 215 | 43.4 | 4.71 |
| CD (0.05) | NS | NS | NS | 0.004 | NS | NS | 0.07 | NS | NS | 2.0 | 0.14 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.59 | 0.260 | 1.66 | 0.154 | 0.125 | 1032 | 0.76 | 1693 | 228 | 43.7 | 4.61 |
| $Si_{500}$ | 1.46 | 0.273 | 1.65 | 0.153 | 0.122 | 952 | 0.77 | 1909 | 203 | 42.3 | 5.03 |
| CD (0.05) | 0.08 | 0.010 | NS | NS | NS | NS | NS | 110 | 12 | NS | 0.12 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.52 | 0.262 | 1.60 | 0.156 | 0.126 | 947 | 0.79 | 1854 | 216 | 44.0 | 4.87 |
| $K_{70}$ | 1.53 | 0.271 | 1.71 | 0.151 | 0.121 | 1037 | 0.74 | 1747 | 216 | 42.0 | 4.76 |
| CD (0.05) | NS | NS | 0.08 | 0.003 | 0.004 | NS | NS | 110 | NS | NS | NS |

Ca, Mg, S, Na, Fe, Mn, Zn and $SiO_2$ over fine silica were 14.4, 17.0, 23.0, 25.9, 23.4, 30.7, 27.8, 22.7, 18.6, 7.8 and 48.8 per cent. The increases in uptake of N, Ca, Mg, Na, Fe, Mn and $SiO_2$ over rice husk were 8.6, 11.6, 9.6, 31.7, 7.9, 9.2 and 23.3 per cent. Between rice husk and fine silica, rice husk recorded the highest uptake of P, Ca, Mg, Zn and $SiO_2$ and the increases were 10.7, 12.9, 12.6, 6.0 and 20.7 per cent respectively.

*b. Levels of silica*

Higher level of silica significantly increased the uptake of P, K, Ca, Mg, Na, Fe, Zn and $SiO_2$ and the increases were 18.7, 12.2, 11.0, 10.0, 12.3, 25.8, 9.5 and 21.8 per cent respectively.

*c. Levels of K*

Increasing the level of K from 52.5 to 70 kg ha$^{-1}$ influenced only the P uptake significantly.

4.1.5.3 Two factor interaction effects on nutrient content and uptake at flowering (Table 23)

*Interaction effect between sources and levels of silica*

*a. Nutrient content*

Data on the two factor interaction between the sources and levels of silica showed significant effect on nutrient content. Application of 500 kg Si as sodium silicate decreased the Fe and Mn content over 250 kg ha$^{-1}$ by 12.5 and 30.9 per cent. But fine silica at 500 kg Si level increased the Na and Fe content by 14.5 and 11.9 per cent over 250 kg Si ha$^{-1}$. Application of 500 kg Si ha$^{-1}$ as rice husk increased the Fe content and reduced the Zn and $SiO_2$ content by 30.6, 10.9 and 9.6 per cent respectively.

*b. Nutrient uptake*

Combined effect of source and level of silica on nutrient uptake showed that application of sodium silicate at 500 kg Si ha$^{-1}$ decreased the Fe and Mn

**Table 22. Effects of Treatments on nutrient uptake (kg ha$^{-1}$) of rice at flowering**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 173 | 25.78 | 162 | 17.31 | 11.56 | 12.5 | 81 | 23.34 | 2.35 | 0.453 | 529 |
| Rest | 223 | 39.24 | 244 | 22.57 | 18.20 | 14.6 | 113 | 26.49 | 3.17 | 0.628 | 714 |
| CD (0.05) | 22 | 4.68 | 34 | 2.02 | 1.49 | NS | 16 | 2.93 | 0.33 | 0.05 | 62 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 239 | 42.04 | 267 | 25.17 | 20.05 | 16.2 | 133 | 28.78 | 3.45 | 0.647 | 863 |
| Fine silica | 209 | 35.92 | 217 | 19.99 | 16.25 | 12.4 | 104 | 23.46 | 2.91 | 0.600 | 580 |
| Rice husk | 220 | 39.77 | 248 | 22.56 | 18.30 | 15.2 | 101 | 26.67 | 3.16 | 0.636 | 700 |
| CD (0.05) | 15 | 3.18 | 23 | 1.37 | 1.01 | 2.9 | 11 | 1.99 | 0.23 | 0.034 | 42 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 218 | 35.89 | 230 | 21.40 | 17.33 | 14.4 | 106 | 23.59 | 3.19 | 0.599 | 644 |
| $Si_{500}$ | 227 | 42.60 | 258 | 23.75 | 19.07 | 14.8 | 119 | 29.68 | 3.16 | 0.656 | 785 |
| CD (0.05) | NS | 2.59 | 19 | 1.12 | 0.83 | NS | 9 | 1.63 | NS | 0.028 | 34 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 218 | 37.77 | 231 | 22.61 | 18.20 | 13.7 | 116 | 27.02 | 3.15 | 0.630 | 713 |
| $K_{70}$ | 228 | 40.72 | 256 | 22.54 | 18.20 | 15.5 | 109 | 26.25 | 3.20 | 0.625 | 715 |
| CD (0.05) | NS | 2.59 | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**Table 23.Two factor interaction effects on nutrient content and uptake of rice at flowering**

| Treatments | Na (%) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.85 | 0.81 | 1924 | 1683 | 256 | 177 | 39 | 42 | 1.80 | 1.95 |
| Fine silica | 0.71 | 0.83 | 1636 | 1857 | 214 | 218 | 45 | 44 | 2.91 | 2.78 |
| Rice husk | 0.72 | 0.66 | 1518 | 2186 | 215 | 216 | 46 | 41 | 3.31 | 3.01 |
| CD (0.05) | 0.10 | | 155 | | 17 | | 3.0 | | 0.25 | |

| Treatments | Ca uptake (kg ha$^{-1}$) | | Mg uptake (kg ha$^{-1}$) | | Fe uptake (kg ha$^{-1}$) | | Mn uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 26.2 | 24.2 | 20.6 | 19.5 | 30.5 | 27.0 | 4.1 | 2.9 | 852 | 875 |
| Fine silica | 17.4 | 22.6 | 14.4 | 18.1 | 19.3 | 27.6 | 2.6 | 3.3 | 516 | 644 |
| Rice husk | 20.6 | 24.6 | 16.9 | 19.7 | 20.9 | 34.4 | 3.0 | 3.4 | 563 | 836 |
| CD (0.05) | 1.9 | | 1.4 | | 2.8 | | 0.3 | | 59 | |

| Treatments | Ca (%) | | Fe (ppm) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.158 | 0.157 | 1881 | 1727 | 228 | 205 | 1.74 | 2.02 |
| Fine silica | 0.150 | 0.148 | 1859 | 1634 | 187 | 245 | 2.80 | 2.88 |
| Rice husk | 0.159 | 0.147 | 1823 | 1881 | 233 | 197 | 3.27 | 3.05 |
| CD (0.05) | 0.006 | | 155 | | 17 | | 0.25 | |

uptake by 11.5 and 29.3 per cent. However, in the case of fine silica and rice husk increasing level of Si from 250 kg to 500 kg ha$^{-1}$ increased the Ca, Mg, Na, Fe, Mn, and $SiO_2$ uptake.

*Interaction effect between sources of silica and levels of K*

*a. Nutrient content*

Sodium silicate at 70 kg K ha$^{-1}$ reduced Mn content and increased the $SiO_2$ content by 10.1 and 16.1 per cent, respectively. In the case of fine silica, increasing the level of K decreased the Fe content and increased the Mn content by 12.1 and 31.0 per cent. Rice husk with increased level of K significantly reduced the Ca and Mn content by 7.6 and 15.5 per cent.

*b. Nutrient uptake*

Increased level of K with sodium silicate decreased the Ca, Mg, Na, Fe, Mn, Zn and $SiO_2$ uptake by 7.3, 11.7, 22.1, 14.8, 18.4, 9.4 and 7.7 per cent respectively. However application of fine silica with increased level of K increased the Ca, Mg, Mn and $SiO_2$ uptake by 10.5, 9.7, 52.2 and 21.8 per cent. Rice husk with increased level of K had no effect on nutrient uptake.

*Interaction effect between levels of silica and K*

Increasing the level of K at higher level of silica decreased the Fe and Zn uptake. But increasing the level of Si at lower level of K increased the Fe and Zn uptake.

4.1.5.4 Three factor interaction effect of sources, levels of silica and levels of K (Table 24)

*a. Nutrient content*

Application of sodium silicate at 250 kg Si decreased the Mg and $SiO_2$ content by 8.8 and 7.7 per cent at increased level of K. At 500 kg Si ha$^{-1}$ the Mn content was decreased whereas the Zn and $SiO_2$ content were increased by 14.7,

**Table 23 continued...**

| Treatments | Ca uptake (kg ha$^{-1}$) | | Mg uptake (kg ha$^{-1}$) | | Na uptake (kg ha$^{-1}$) | | Fe uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 26.1 | 24.2 | 21.3 | 18.8 | 149 | 116 | 31.1 | 26.5 |
| Fine silica | 19.0 | 21.0 | 15.5 | 17.0 | 97 | 111 | 23.5 | 22.9 |
| Rice husk | 22.7 | 22.5 | 17.8 | 18.8 | 101 | 103 | 26.5 | 28.9 |
| CD (0.05) | 1.9 | | 1.4 | | 16 | | 2.8 | |

| Treatments | Mn uptake (kg ha$^{-1}$) | | Zn uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 3.8 | 3.1 | 0.679 | 0.615 | 898 | 829 |
| Fine silica | 2.3 | 3.5 | 0.579 | 0.621 | 523 | 637 |
| Rice husk | 3.3 | 3.0 | 0.633 | 0.640 | 719 | 680 |
| CD (0.05) | 0.3 | | 0.048 | | 59 | |

| Treatments | Fe uptake (kg ha$^{-1}$) | | Zn uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 23.0 | 24.2 | 0.58 | 0.62 |
| Si500 | 31.1 | 28.3 | 0.68 | 0.63 |
| CD (0.05) | 2.3 | | 0.04 | |

10.0 and 6.8 per cent. Increased level of K decreased the Mg content at 250 kg Si level as fine silica but it also increased the Mn and $SiO_2$ content significantly.

The increase in silica application as fine silica from 250 kg to 500 kg $ha^{-1}$ decreased the Ca and Fe content but increased the Mn, Zn and $SiO_2$ content significantly. With respect to rice husk the increase in K level at 250 kg Si $ha^{-1}$ decreased the N, Ca, Zn and Si content by 11.5, 8.9, 8.3 and 11.5 per cent and increased the Fe content by 23.6 per cent. The increase in silica level from 250 kg to 500 kg $ha^{-1}$ significantly reduced the Ca, Fe, Mn, Zn and $SiO_2$ by 6.3, 12.5, 31.6, 17.8 and 11.4 per cent respectively.

*b. Nutrient uptake*

Data on three factor interaction effect on nutrient uptake showed that application of sodium silicate at 250 kg $ha^{-1}$ decreased the N, Ca, Mg, Fe, Mn, Zn and $SiO_2$ uptake by 12.7, 10.8, 20.9, 18.7, 19.6, 12.1 and 20.4 per cent respectively with increasing levels of K. At 52.5 kg K, application of increased level of silica as sodium silicate significantly decreased the N, Mg, Fe, Mn and $SiO_2$ uptake. But in the case of fine silica at 250 kg $ha^{-1}$, increased level of K increased the N, Ca, Zn and $SiO_2$ uptake by 36.1, 39.0, 20.0 and 31.2 per cent. In the case of higher level the effect was confined to Mg, Fe and Zn uptake only. Rice husk at 250 kg $ha^{-1}$, increased the Mg, Fe and Zn uptake by 13.2, 41.6 and 17.2 per cent with increased levels of K. At higher level the Mn and Zn uptake was significantly reduced by 28.0 and 13.0 per cent.

4.1.6 Effects of treatments on nutrient content and uptake of straw at harvest (Table 25)

4.1.6.1 Effects of treatments on nutrient content.

The over all treatment effect decreased the N, Mg, S, Na and Zn content by 18.5, 7.4, 17.6, 11.7 and 2.5 per cent but increased the Ca content by 8.0 per cent over control.

**Table 24.Three factor interaction effects on nutrient content and uptake of rice at Flowering**

| Treatments | N (%) | | Ca (%) | | Mg (%) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K52.5 | K70.0 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 1.49 | 1.52 | 0.163 | 0.168 | 0.136 | 0.124 | 1980 | 1869 | 265 | 246 | 40 | 39 | 5.58 | 5.15 |
| Sodium silicate Si500 | 1.42 | 1.56 | 0.153 | 0.147 | 0.122 | 0.121 | 1781 | 1586 | 191 | 163 | 40 | 44 | 5.27 | 5.63 |
| Fine silica Si250 | 1.61 | 1.75 | 0.138 | 0.154 | 0.128 | 0.116 | 1709 | 1563 | 187 | 241 | 45 | 47 | 4.23 | 4.45 |
| Fine silica Si500 | 1.52 | 1.40 | 0.162 | 0.142 | 0.122 | 0.121 | 2010 | 1705 | 186 | 249 | 42 | 46 | 4.17 | 4.48 |
| Rice husk Si250 | 1.66 | 1.47 | 0.157 | 0.143 | 0.121 | 0.126 | 1315 | 1721 | 209 | 220 | 48 | 44 | 4.36 | 3.86 |
| Rice husk Si500 | 1.40 | 1.45 | 0.160 | 0.50 | 0.128 | 0.121 | 2331 | 2040 | 256 | 175 | 37 | 45 | 5.62 | 4.98 |
| CD (0.05) | 0.19 | | 0.008 | | 0.009 | | 219 | | 23 | | 4 | | 0.29 | |

| Treatments | N uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | Mg uptake (kg $ha^{-1}$) | | Fe uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | | Zn uptake (kg $ha^{-1}$) | | $SiO_2$ uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 254.5 | 222.2 | 27.7 | 24.7 | 23.0 | 18.2 | 33.7 | 27.4 | 4.50 | 3.62 | 0.66 | 0.58 | 949 | 755 |
| Sodium silicate Si500 | 228.5 | 251.2 | 25.3 | 23.7 | 19.6 | 19.4 | 28.6 | 25.5 | 3.07 | 2.62 | 0.70 | 0.65 | 847 | 903 |
| Fine silica Si250 | 169.2 | 230.2 | 14.6 | 20.3 | 13.5 | 15.3 | 18.0 | 20.7 | 1.96 | 3.17 | 0.50 | 0.60 | 445 | 587 |
| Fine silica Si500 | 218.6 | 216.9 | 23.4 | 21.7 | 17.6 | 18.6 | 29.0 | 26.2 | 2.69 | 3.81 | 0.66 | 0.65 | 601 | 687 |
| Rice husk Si250 | 215.7 | 212.9 | 20.7 | 20.4 | 15.9 | 18.0 | 17.3 | 24.5 | 2.76 | 3.14 | 0.58 | 0.68 | 576 | 551 |
| Rice husk Si500 | 214.7 | 233.3 | 25.8 | 24.6 | 19.6 | 19.7 | 35.7 | 33.2 | 3.93 | 2.83 | 0.69 | 0.60 | 862 | 810 |
| CD (0.05) | 30.4 | | 2.8 | | 2.0 | | 4.0 | | 0.45 | | 0.07 | | 84 | |

*a. Sources of silica*

Sodium silicate applied treatments significantly decreased the Ca, S, Fe, Mn and Zn contents by 7.5, 23.5, 16.7, 12.5 and 5.2 per cent and increased the Mg, Na and $SiO_2$ content by 5.0, 10.0 and 7.4 per cent over fine silica. It also decreased K, Ca, S, Fe, Mn and Zn contents by 10.4, 6.0, 14.2, 15.2, 18.5, 15.0 and 13.4 per cent over rice husk. Between rice husk and fine silica, rice husk decreased S and Na content but increased K and Zn.

*b. Levels of silica*

Increased levels of silica increased Ca and $SiO_2$ content but reduced S content. The effect was not significant on other nutrients.

*c. Levels of K*

The effect of increased levels of K was confined only to the P content.

4.1.6.2 Effects of treatments on nutrient uptake of straw at harvest (Table 26)

The general treatment effects were significantly reduced the uptake of N, Mg, S, Na, Mn and Zn by 21.3, 9.4, 5.5, 13.0, 5.7 and 17.1 per cent, but increased the Ca uptake from 10.9 to 11.4 kg $ha^{-1}$..

*a. Sources of silica*

Different sources of silica varied significantly in the uptake of native elements. Sodium silicate increased the uptake of N, P, K, Ca, Mg, Na, Zn and $SiO_2$ by 20.0, 12.7, 14.1, 5.4, 20.5, 27.9, 11.1 and 23.7 per cent over fine silica. In comparison to rice husk, the increases in the uptake of K, Mg, Fe, and Zn was 14.1, 6.8, 5.3 and 14.8 per cent respectively.

*b. Levels of silica*

Increasing the level of silica significantly increased the uptake of K, Ca, Mg, Na, Fe, Mn, Zn and $SiO_2$.

**Table 25. Effects of treatments on nutrient content of straw at harvest**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 1.19 | 0.123 | 2.13 | 0.276 | 0.135 | 1731 | 1.37 | 1531 | 898 | 87.7 | 5.30 |
| Rest | 0.97 | 0.130 | 2.26 | 0.298 | 0.125 | 1427 | 1.21 | 1504 | 867 | 76.7 | 5.33 |
| CD (0.05) | 0.21 | NS | NS | 0.008 | 0.006 | 253 | 0.06 | NS | NS | 4.7 | NS |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 1.01 | 0.128 | 2.15 | 0.284 | 0.127 | 1233 | 1.32 | 1317 | 784 | 71.7 | 5.68 |
| Fine silica | 0.96 | 0.131 | 2.17 | 0.307 | 0.121 | 1612 | 1.20 | 1579 | 896 | 75.6 | 5.29 |
| Rice husk | 0.94 | 0.131 | 2.40 | 0.302 | 0.127 | 1437 | 1.12 | 1616 | 922 | 82.8 | 5.01 |
| CD (0.05) | NS | NS | 0.11 | 0.006 | 0.004 | 172 | 0.04 | 60 | 39 | 3.2 | 0.12 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.96 | 0.132 | 2.25 | 0.292 | 0.123 | 1514 | 1.19 | 1510 | 877 | 75.4 | 5.16 |
| $Si_{500}$ | 0.98 | 0.128 | 2.36 | 0.304 | 0.127 | 1340 | 1.24 | 1498 | 858 | 77.9 | 5.49 |
| CD (0.05) | NS | NS | NS | 0.005 | NS | 140 | NS | NS | NS | NS | 0.10 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 0.95 | 0.125 | 2.28 | 0.300 | 0.125 | 1499 | 1.24 | 1528 | 868 | 77.6 | 5.30 |
| $K_{70}$ | 1.00 | 0.135 | 2.20 | 0.296 | 0.125 | 1356 | 1.19 | 1480 | 867 | 75.8 | 5.35 |
| CD (0.05) | NS | 0.007 | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*a. Sources of silica*

Sodium silicate applied treatments significantly decreased the Ca, S, Fe, Mn and Zn contents by 7.5, 23.5, 16.7, 12.5 and 5.2 per cent and increased the Mg, Na and $SiO_2$ content by 5.0, 10.0 and 7.4 per cent over fine silica. It also decreased K, Ca, S, Fe, Mn and Zn contents by 10.4, 6.0, 14.2, 15.2, 18.5, 15.0 and 13.4 per cent over rice husk. Between rice husk and fine silica, rice husk decreased S and Na content but increased K and Zn.

*b. Levels of silica*

Increased levels of silica increased Ca and $SiO_2$ content but reduced S content. The effect was not significant on other nutrients.

*c. Levels of K*

The effect of increased levels of K was confined only to the P content.

4.1.6.2 Effects of treatments on nutrient uptake of straw at harvest (Table 26)

The general treatment effects were significantly reduced the uptake of N, Mg, S, Na, Mn and Zn by 21.3, 9.4, 5.5, 13.0, 5.7 and 17.1 per cent, but increased the Ca uptake from 10.9 to 11.4 kg $ha^{-1}$..

*a. Sources of silica*

Different sources of silica varied significantly in the uptake of native elements. Sodium silicate increased the uptake of N, P, K, Ca, Mg, Na, Zn and $SiO_2$ by 20.0, 12.7, 14.1, 5.4, 20.5, 27.9, 11.1 and 23.7 per cent over fine silica. In comparison to rice husk, the increases in the uptake of K, Mg, Fe, and Zn was 14.1, 6.8, 5.3 and 14.8 per cent respectively.

*b. Levels of silica*

Increasing the level of silica significantly increased the uptake of K, Ca, Mg, Na, Fe, Mn, Zn and $SiO_2$.

**Table 26. Effects of Treatments on nutrient uptake (kg ha$^{-1}$) of straw at harvest**

| **Treatments** | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 47 | 4.8 | 84 | 10.9 | 5.3 | 6.9 | 54 | 6.0 | 3.5 | 0.35 | 209 |
| Rest | 37 | 5.0 | 85 | 11.4 | 4.8 | 5.5 | 47 | 5.7 | 3.3 | 0.29 | 203 |
| CD (0.05) | 8 | NS | NS | 0.5 | 0.3 | 1.0 | 5 | NS | 0.2 | 0.02 | NS |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 42 | 5.3 | 89 | 11.7 | 5.3 | 5.1 | 55 | 5.4 | 3.2 | 0.30 | 235 |
| Fine silica | 35 | 4.7 | 78 | 11.1 | 4.4 | 5.8 | 43 | 5.7 | 3.2 | 0.27 | 190 |
| Rice husk | 35 | 4.8 | 89 | 11.3 | 4.7 | 5.3 | 42 | 6.0 | 3.4 | 0.31 | 185 |
| CD (0.05) | 6 | 0.3 | 5 | 0.3 | 0.2 | NS | 3 | 0.2 | 0.1 | 0.01 | 6 |
| *Levels of silica* $Si_{250}$ | 35 | 4.9 | 83 | 10.7 | 4.5 | 5.6 | 44 | 5.6 | 3.2 | 0.28 | 190 |
| $Si_{500}$ | 39 | 5.1 | 88 | 12.0 | 5.0 | 5.2 | 49 | 5.9 | 3.4 | 0.31 | 216 |
| CD (0.05) | NS | NS | 4 | 0.3 | 0.2 | NS | 3 | 0.2 | NS | 0.01 | 5 |
| *Levels of Potash* $K_{52.5}$ | 36 | 4.7 | 87 | 11.4 | 4.8 | 5.7 | 47 | 5.8 | 3.3 | 0.30 | 201 |
| $K_{70}$ | 38 | 5.2 | 84 | 11.3 | 4.9 | 5.8 | 46 | 5.7 | 3.3 | 0.29 | 206 |
| CD (0.05) | NS | 0.3 | NS | NS | NS | NS | NS | NS | NS | NS | 5 |

*c. Levels of K*

Increasing the level of K from 52.5 to 70 kg $ha^{-1}$ increased the uptake of P and $SiO_2$ by 10.6, and 2.5 per cent respectively.

4.1.6.3 Two factor interaction effects on nutrient content and nutrient uptake of straw at harvest (Table 27)

*Interaction effect between sources and levels of silica*

*a. Nutrient content*

Data on interaction effect between sources and levels of silica showed that increasing the level of sodium silicate from 250 to 500 kg Si $ha^{-1}$ increased the Mg and $SiO_2$ content by 17.1 and 5.5 per cent and decreased the Fe and Mn content by 14.4 and 25.5 per cent. Increasing level of fine silica increased the Ca, Fe, Mn and $SiO_2$ content by 4.7, 9.4, 8.9 and 24.2 per cent. In the case of rice husk, increasing the level of silica increased the Ca, Mn and $SiO_2$ content by 7.2, 11.0 and 9.9 per cent.

*b. Nutrient uptake*

The data revealed that the increasing level of silica as sodium silicate increased the Mg and $SiO_2$ uptake by 27.8 and 14.6 per cent. Fine silica and rice husk also having significant interaction with levels of silica.

*Interaction effect between sources of silica and levels of K*

*a. Nutrient content*

Application of sodium silicate with increasing level of K increased the P, Ca and $SiO_2$ content by 13.3, 2.9 and 7.7 per cent and reduced the Fe and Mn content by 13.3 and 8.7 per cent with increasing level of K. In the case of fine silica, the effect was confined to P content only. However, rice husk increased the P content and reduced the K, Ca and $SiO_2$ content by 20.2, 13.2, 3.9 and 5.8 per cent.

**Table 27.Two factor interaction effects on nutrient content and uptake of Straw at harvest**

| Treatments | Ca (%) | | Mg (%) | | Fe (ppm) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.283 | 0.286 | 0.117 | 0.137 | 1419 | 1215 | 899 | 670 | 5.52 | 5.84 |
| Fine silica | 0.300 | 0.314 | 0.122 | 0.119 | 1508 | 1650 | 858 | 934 | 4.72 | 5.86 |
| Rice husk | 0.292 | 0.313 | 0.132 | 0.123 | 1604 | 1629 | 874 | 970 | 5.24 | 4.77 |
| CD (0.05) | 0.008 | | 0.006 | | 84 | | 54 | | 0.17 | |

| Treatments | K uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | Mg uptake (kg $ha^{-1}$) | | Fe uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | | Zn uptake (kg $ha^{-1}$) | | $SiO_2$ uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 86.4 | 91.2 | 11.19 | 12.26 | 4.61 | 5.89 | 5.62 | 5.21 | 3.56 | 2.87 | 0.281 | 0.311 | 219 | 251 |
| Fine silica | 79.4 | 77.2 | 11.04 | 11.10 | 4.48 | 4.21 | 5.54 | 5.83 | 3.15 | 3.30 | 0.274 | 0.271 | 173 | 207 |
| Rice husk | 82.2 | 96.0 | 9.98 | 12.49 | 4.50 | 4.91 | 5.49 | 6.51 | 2.99 | 3.88 | 0.277 | 0.339 | 179 | 191 |
| CD (0.05) | 6.2 | | 0.43 | | 0.26 | | 0.32 | | 0.20 | | 0.018 | | 8 | |

| Treatments | P (%) | | K (%) | | Ca (%) | | Fe (ppm) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.120 | 0.136 | 2.16 | 2.15 | 0.288 | 0.280 | 1411 | 1223 | 820 | 749 | 5.47 | 5.89 |
| Fine silica | 0.138 | 0.125 | 2.12 | 2.23 | 0.303 | 0.311 | 1556 | 1602 | 878 | 913 | 5.28 | 5.30 |
| Rice husk | 0.119 | 0.143 | 2.57 | 2.23 | 0.308 | 0.296 | 1616 | 1647 | 907 | 937 | 5.16 | 4.86 |
| CD (0.05) | 0.011 | | 0.16 | | 0.008 | | 84 | | 54 | | 0.17 | |

**Table 27. Continued...**

| Treatments | P uptake (kg ha$^{-1}$) | | K uptake (kg ha$^{-1}$) | | Na uptake (kg ha$^{-1}$) | | Fe uptake (kg ha$^{-1}$) | | Zn uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 4.83 | 5.73 | 87.3 | 90.3 | 53.6 | 55.3 | 5.69 | 5.13 | 0.288 | 0.304 | 221 | 249 |
| Fine silica | 4.93 | 4.48 | 76.9 | 79.7 | 46.6 | 40.0 | 5.65 | 5.73 | 0.205 | 0.260 | 191 | 189 |
| Rice husk | 4.41 | 5.28 | 95.9 | 82.3 | 41.0 | 42.3 | 6.01 | 5.99 | 0.310 | 0.305 | 190 | 180 |
| CD (0.05) | 0.47 | | 6.2 | | 4.5 | | 0.32 | | 0.018 | | 8 | |

| Treatments | N (%) | | P (%) | | S (ppm) | | Ca (%) | | Mg (%) | | Fe (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.86 | 1.05 | 0.133 | 0.130 | 1677 | 1352 | 0.283 | 0.301 | 0.127 | 0.119 | 1563 | 1458 | 5.33 | 4.99 |
| Si500 | 1.03 | 0.94 | 0.118 | 0.139 | 1320 | 1360 | 0.317 | 0.291 | 0.123 | 0.130 | 1493 | 1503 | 5.27 | 5.71 |
| CD (0.05) | 0.16 | | 0.009 | | 199 | | 0.007 | | 0.005 | | 69 | | 0.14 | |

| Treatments | N uptake (kg ha$^{-1}$) | | P uptake (kg ha$^{-1}$) | | Ca uptake (kg ha$^{-1}$) | | Mg uptake (kg ha$^{-1}$) | | S uptake (kg ha$^{-1}$) | | Fe uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 31.9 | 38.8 | 4.87 | 4.81 | 10.37 | 11.11 | 4.67 | 4.40 | 6.16 | 4.97 | 5.73 | 5.37 | 195 | 186 |
| Si500 | 40.4 | 37.4 | 4.58 | 5.52 | 12.41 | 11.48 | 4.84 | 5.17 | 5.15 | 5.33 | 5.83 | 5.87 | 206 | 226 |
| CD (0.05) | 6.4 | | 0.39 | | 0.36 | | 0.22 | | 0.78 | | 0.26 | | 6.4 | |

*b. Nutrient uptake*

Data on interaction effect on nutrient uptake showed that application of sodium silicate with increasing levels of K increased the P and $SiO_2$ uptake by 18.6 and 12.7. In the case of fine silica the effect was confined to Zn uptake only. But increased level of K increased the P uptake by 19.7 and decreased the K and $SiO_2$ uptake by 14.2 and 5.3 per cent in respect of rice husk.

*Interaction effect between levels of silica and K*

*a. Nutrient content*

Combined effect of levels of silica and K increased the N, S and Ca content and reduced the Mg, Fe and $SiO_2$ content at 250 kg Si $ha^{-1}$. At 52.5 kg K increasing the level of silica decreased the P, S, Fe and $SiO_2$ content by 11.3, 21.3, 4.5 and 2.6 per cent. At 500 kg Si $ha^{-1}$, increasing the level of K increased the P, Mg and $SiO_2$ content by 17.8, 5.9 and 8.9 per cent respectively.

*b. Nutrient uptake*

Application of 250 kg Si $ha^{-1}$ with increasing levels of K increased the N and Ca uptake and decreased the Mg, S, Fe and $SiO_2$ uptake by 21.6, 7.1, 5.8, 19.3, 6.3 and 4.6 per cent respectively. But at 500 kg Si $ha^{-1}$, the variation in level of K increased the P, Mg and $SiO_2$ uptake by 20.5, 6.8 and 9.7 per cent and decreased the Ca uptake by 7.5 per cent.

4.1.6.4 Three factor interaction effect of sources and levels of silica and levels of K on nutrient content and uptake (Table 28)

Application of 250 kg Si $ha^{-1}$ as sodium silicate with the higher level of K increased the Ca content by 4.7 per cent. At 500 kg $ha^{-1}$ level the increase in K application increased the P and $SiO_2$ content and reduced the Ca content by 34.6, 11.1 and 9.7 per cent. In the case of fine silica at 250 kg $ha^{-1}$ increasing the application of K increased the Ca content but at 500 kg $ha^{-1}$ Ca content was reduced. Application of rice husk at 500 kg Si $ha^{-1}$ along with increased level of K

**Table 28. Three factor interaction effects on nutrient content and uptake of Straw at harvest**

| Treatments | P (%) | | Ca (%) | | Si (%) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 0.133 | 0.127 | 0.276 | 0.289 | 5.43 | 5.60 |
| Sodium silicate Si500 | 0.107 | 0.144 | 0.300 | 0.271 | 5.50 | 6.11 |
| Fine silica Si250 | 0.134 | 0.126 | 0.277 | 0.324 | 4.74 | 4.69 |
| Fine silica Si500 | 0.138 | 0.124 | 0.329 | 0.298 | 5.81 | 5.90 |
| Rice husk Si250 | 0.131 | 0.138 | 0.295 | 0.289 | 5.81 | 4.68 |
| Rice husk Si500 | 0.107 | 0.148 | 0.321 | 0.304 | 4.51 | 5.04 |
| CD (0.05) | 0.016 | | 0.011 | | 0.24 | |

| Treatments | P uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | Mg uptake (kg $ha^{-1}$) | | $SiO_2$ uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 5.18 | 5.10 | 10.78 | 11.60 | 4.75 | 4.47 | 213 | 225 |
| Sodium silicate Si500 | 4.49 | 6.36 | 12.53 | 11.98 | 5.65 | 6.13 | 230 | 273 |
| Fine silica Si250 | 4.97 | 4.58 | 10.28 | 11.80 | 4.76 | 4.21 | 176 | 171 |
| Fine silica Si500 | 4.89 | 4.37 | 11.69 | 10.50 | 3.97 | 4.45 | 207 | 208 |
| Rice husk Si250 | 4.46 | 4.74 | 10.05 | 9.95 | 4.49 | 4.52 | 197 | 161 |
| Rice husk Si500 | 4.35 | 5.82 | 13.01 | 11.97 | 4.88 | 4.93 | 182 | 199 |
| CD (0.05) | 0.67 | | 0.61 | | 0.37 | | 11 | |

increased the P and $SiO_2$ content but reduced the Ca content by 38.3, 11.8 and 15.3 per cent, respectively.

Data on uptake showed that the application of 500 kg Si $ha^{-1}$ as sodium silicate, with enhanced level of K, significantly increased the P, Mg and $SiO_2$ uptake by 41.6, 8.5 and 18.7 per cent. In the case of fine silica, the effect was confined to Ca and Mg uptake at 250 kg $ha^{-1}$ level. Rice husk increased the P and $SiO_2$ uptake by 33.8 and 9.3 per cent at 500 kg Si $ha^{-1}$ level.

4.1.7 Effects of treatments on nutrient content and uptake of grain at harvest

4.1.7.1 Effects of treatments on nutrient content (Table 29)

The applied treatments increased the N, P, Mn and $SiO_2$ content of grain by 22.8,16.2, 14.1,and 31.8 per cent and decreased the Fe content by 14.6 per cent.

*a. Sources of silica*

Application of sodium silicate decreased the Mn, Fe and $SiO_2$ content by 16.9, 7.4 and 21.9 per cent and increased the P content by 11.8 per cent over rice husk. Between rice husk and fine silica, fine silica increased the P, Mn and Zn content by 8.7,16.4 and 6.8 per cent but decreased the Fe and $SiO_2$ content by 8.6 and 13.6 per cent respectively.

*b. Levels of silica*

Increasing level of silica from 250 kg to 500 kg $ha^{-1}$ increased the Mn content by 14.1 per cent but the contents of other nutrients remain unaffected.

*c. Levels of K*

Application of 70 kg K $ha^{-1}$ decreased the Ca content but increased the Fe content by 10.7 and 7.3 per cent.

4.1.7.2 Effects of treatments on nutrient uptake of grain at harvest (Table 30)

Combined application of silica and K significantly increased the N, P, K, Ca, Mg, Mn, Zn and $SiO_2$ uptake over control.

**Table 29. Effects of Treatments on nutrient content of grain at harvest**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.92 | 0.117 | 0.52 | 0.025 | 0.092 | 965 | 0.050 | 294 | 34.7 | 17.0 | 2.01 |
| Rest | 1.13 | 0.136 | 0.52 | 0.027 | 0.094 | 954 | 0.053 | 251 | 39.6 | 18.2 | 2.65 |
| CD (0.05) | 0.13 | 0.014 | NS | NS | NS | NS | NS | 26 | 3.7 | NS | 0.58 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 1.13 | 0.142 | 0.52 | 0.028 | 0.093 | 868 | 0.050 | 237 | 32.9 | 18.3 | 2.35 |
| Fine silica | 1.15 | 0.138 | 0.52 | 0.025 | 0.091 | 987 | 0.054 | 234 | 46.1 | 18.8 | 2.60 |
| Rice husk | 1.10 | 0.127 | 0.53 | 0.027 | 0.097 | 1006 | 0.054 | 256 | 39.6 | 17.6 | 3.01 |
| CD (0.05) | NS | 0.009 | NS | 0.002 | NS | NS | NS | 18 | 2.5 | 0.93 | 0.39 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.11 | 0.134 | 0.52 | 0.027 | 0.094 | 980 | 0.056 | 244 | 42.1 | 18.6 | 2.69 |
| $Si_{500}$ | 1.14 | 0.137 | 0.53 | 0.026 | 0.094 | 928 | 0.050 | 241 | 36.9 | 17.9 | 2.62 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | 2.1 | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.11 | 0.134 | 0.52 | 0.028 | 0.095 | 1000 | 0.053 | 234 | 39.9 | 18.5 | 2.63 |
| $K_{70}$ | 1.15 | 0.137 | 0.53 | 0.025 | 0.093 | 907 | 0.053 | 251 | 39.2 | 17.9 | 2.68 |
| CD (0.05) | NS | NS | NS | 0.001 | NS | NS | NS | 15 | NS | NS | NS |

*a. Sources of silica*

Data on nutrient uptake revealed that application of sodium silicate recorded the highest uptake of P, Ca, Mg and Zn and lowest uptake of Mn over fine silica and rice husk.

*b. Levels of silica*

Application of 500 kg Si significantly increased the N, P, K, Ca, Mg, Fe and Zn uptake over 250 kg Si $ha^{-1}$ level.

*c. Levels of K*

Increasing the level of K from 52.5 to 70 kg increased the Fe uptake and decreased the Ca uptake by 6.7 and 11.1 per cent respectively.

4.1.7.3 Two factor interaction effects on nutrient content and uptake of grain at harvest (Table 31)

*Interaction effect between sources and levels of silica*

*a. Nutrient content*

The application of sodium silicate, with increasing levels of silica, reduced the Ca and Mn content by 13.3 and 38.1 per cent. However application of fine silica increased the N, Ca and Mg content by 16.0,17.4 and 9.2 per cent but decreased the S and $SiO_2$ content by 16.3 and 24.0 per cent. The effect of rice husk was confined to N and $SiO_2$ content only.

*b. Nutrient uptake*

Application of sodium silicate at 500 kg Si $ha^{-1}$ level increased the N and S uptake and reduced the Mn uptake by 17.4,36.7 and 30.8 per cent respectively. Fine silica increased the N, Ca and Mn uptake by 26.6, 23.4 and 7.1 per cent. Rice husk increased the Ca and $SiO_2$ uptake by 10.9, and 55.9 per cent respectively.

*Interaction effect between sources of silica and levels of K on nutrient content and uptake*

Combined effect of sources of silica and levels of K indicated that application of sodium silicate, with increasing levels of K, increased the Fe content

**Table 30. Effects of Treatments on nutrient uptake (kg ha$^{-1}$) of grain at harvest**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 49 | 6.2 | 27 | 1.3 | 4.9 | 5.1 | 2.7 | 1.6 | 0.18 | 0.09 | 107 |
| Rest | 72 | 8.6 | 33 | 1.7 | 6.0 | 6.0 | 3.3 | 1.6 | 0.25 | 0.12 | 168 |
| CD (0.05) | 8 | 0.9 | 4 | 0.2 | 0.5 | NS | NS | NS | 0.02 | 0.01 | 35 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 75 | 9.5 | 34 | 1.8 | 6.2 | 5.8 | 3.3 | 1.6 | 0.22 | 0.12 | 155 |
| Fine silica | 72 | 8.7 | 33 | 1.6 | 5.7 | 6.2 | 3.4 | 1.5 | 0.29 | 0.12 | 163 |
| Rice husk | 67 | 7.7 | 33 | 1.7 | 5.9 | 6.1 | 3.3 | 1.6 | 0.24 | 0.11 | 186 |
| CD (0.05) | NS | 0.6 | NS | 0.1 | 0.3 | NS | NS | NS | 0.02 | 0.01 | NS |
| *Levels of silica* $Si_{250}$ | 67 | 8.1 | 31 | 1.6 | 5.6 | 5.9 | 3.4 | 1.5 | 0.25 | 0.11 | 162 |
| $Si_{500}$ | 76 | 9.1 | 35 | 1.8 | 6.3 | 6.2 | 3.3 | 1.6 | 0.24 | 0.12 | 173 |
| CD (0.05) | 5 | 0.5 | 2 | 0.1 | 0.3 | NS | NS | 0.1 | NS | 0.01 | NS |
| *Levels of Potash* $K_{52.5}$ | 70 | 8.4 | 33 | 1.8 | 6.0 | 6.2 | 3.3 | 1.5 | 0.25 | 0.12 | 164 |
| $K_{70}$ | 74 | 8.9 | 34 | 1.6 | 6.0 | 5.9 | 3.4 | 1.6 | 0.25 | 0.12 | 171 |
| CD (0.05) | NS | NS | NS | 0.1 | NS | NS | NS | 0.1 | NS | NS | NS |

**Table 31. Two factor interaction effects on nutrient content and uptake of grain at harvest**

| Treatments | N (%) | | Ca (%) | | Mg (%) | | S (ppm) | | Fe (ppm) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.10 | 1.15 | 0.030 | 0.026 | 0.094 | 0.093 | 788 | 948 | 253 | 222 | 40.7 | 25.2 | 2.61 | 2.10 |
| Fine silica | 1.06 | 1.23 | 0.023 | 0.027 | 0.087 | 0.095 | 1075 | 900 | 232 | 236 | 46.5 | 45.7 | 2.96 | 2.25 |
| Rice husk | 1.18 | 1.03 | 0.027 | 0.028 | 0.100 | 0.095 | 1077 | 935 | 247 | 266 | 39.2 | 40.0 | 2.50 | 3.52 |
| CD (0.05) | 0.13 | | 0.002 | | 0.007 | | 174 | | 25 | | 3.6 | | 0.55 | |

| Treatments | N uptake (kg $ha^{-1}$) | | Ca uptake (kg $ha^{-1}$) | | S uptake (kg $ha^{-1}$) | | Mn uptake (kg $ha^{-1}$) | | $SiO_2$ uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 69 | 81 | 1.85 | 1.79 | 4.9 | 6.7 | 0.26 | 0.18 | 164 | 147 |
| Fine silica | 64 | 81 | 1.41 | 1.74 | 6.5 | 5.9 | 0.28 | 0.30 | 178 | 147 |
| Rice husk | 68 | 67 | 1.56 | 1.73 | 6.2 | 6.0 | 0.23 | 0.16 | 145 | 226 |
| CD (0.05) | 8 | | 0.16 | | 1.2 | | 0.02 | | 33 | |

| Treatments | P (%) | | Ca (%) | | Fe (ppm) | | Zn (ppm) | | Fe uptake (kg $ha^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.148 | 0.137 | 0.031 | 0.024 | 211 | 264 | 18.3 | 18.0 | 1.36 | 1.79 |
| Fine silica | 0.129 | 0.147 | 0.026 | 0.025 | 236 | 233 | 19.8 | 17.8 | 1.47 | 1.48 |
| Rice husk | 0.125 | 0.128 | 0.028 | 0.026 | 254 | 258 | 17.3 | 17.8 | 1.54 | 1.59 |
| CD (0.05) | 0.013 | | 0.002 | | 25 | | 1.3 | | 0.19 | |

and Fe uptake by 25.1 and 31.6 per cent but decreased the Ca content by 22.6 per cent. In the case of fine silica application of 70 kg K $ha^{-1}$ increased the p content and reduced the Zn content by 14.0 and 10.1 per cent. Combined effect of rice husk and K was confined to Ca content only.

*Interaction effect between levels of K and silica on nutrient content and uptake*

Application of silica at 250 kg level, with increasing level of K, increased the N and Mn content but decreased the S content by 19.8, 8.4, and 22.6 per cent and decreased the Ca uptake by 16.6 per cent. At 500 kg level of silica, the combined effect increased the N content and S uptake by 6.2, and 18.0 per cent but decreased the Mn content by 12.0 per cent.

#### 4.1.7.4 Three factor interaction effect of sources levels of silica and levels of K on nutrient content and uptake (Table 32)

Application of sodium silicate, with increasing level of K, decreased the Ca content and uptake by 31.4 and 29.2 per cent and increased the $SiO_2$ content and uptake by 60.5 and 41.6 per cent at 250 kg $ha^{-1}$. Application of fine silica at 250 kg increased the Mn content and uptake by 26.2 and 25.7 per cent but decreased the $SiO_2$ content by 21.5 per cent. At 500 kg Si $ha^{-1}$ level increased level of K decreased the Ca and Mn content and uptake by 23.3, 18.0, 21.0 and 16.1 per cent. The combined effect of rice husk was decreased the Ca uptake at 250 kg Si and reduced the Mg and Mn uptake at 500 kg Si $ha^{-1}$.

### 4.1.8 Effects of treatments on nutrient ratios at maximum tillering (Table 33)

Application of different sources of silica with increasing levels of silica and K widened the ratios of N/K, N/Fe, N/Mn, P/Fe and K/Fe and narrowed $N/SiO_2$, $P/SiO_2$, $K/SiO_2$, $Fe/SiO_2$ and $Mn/SiO_2$ ratios significantly over control.

**Table 31. Continued...**

| Treatments | N (%) | | S (ppm) | | Mn (ppm) | | Ca uptake (kg ha$^{-1}$) | | S uptake (kg ha$^{-1}$) | | Mn uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 2.47 | 2.96 | 1104 | 855 | 40.4 | 43.8 | 1.75 | 1.46 | 20.7 | 17.2 | 0.24 | 0.27 |
| Si500 | 2.75 | 2.92 | 897 | 958 | 39.3 | 34.6 | 1.79 | 4.71 | 20.6 | 24.3 | 0.26 | 0.23 |
| CD (0.05) | 0.13 | | 142 | | 2.9 | | 0.13 | | 3.6 | | 0.02 | |

Table 32. **Three factor interaction effects on nutrient content and uptake of grain at harvest**

| Treatments | Ca (%) | | Mn (ppm) | | $SiO_2$ (%) | | Ca uptake (kg ha$^{-1}$) | | Mg uptake (kg ha$^{-1}$) | | Mn uptake (kg ha$^{-1}$) | | $SiO_2$ uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate Si250 | 0.035 | 0.024 | 40 | 41 | 2.00 | 3.21 | 2.16 | 1.53 | 6.12 | 5.65 | 0.252 | 0.258 | 125 | 202 |
| Sodium silicate Si500 | 0.027 | 0.024 | 24 | 26 | 2.47 | 1.73 | 1.82 | 1.75 | 6.24 | 6.82 | 0.164 | 0.190 | 166 | 127 |
| Fine silica Si250 | 0.022 | 0.024 | 42 | 51 | 3.31 | 2.60 | 1.33 | 1.48 | 5.10 | 5.39 | 0.249 | 0.313 | 198 | 159 |
| Fine silica Si500 | 0.030 | 0.023 | 50 | 41 | 1.98 | 2.51 | 1.95 | 1.54 | 6.15 | 6.30 | 0.324 | 0.272 | 128 | 165 |
| Rice husk Si250 | 0.030 | 0.024 | 40 | 39 | 2.54 | 2.46 | 1.75 | 1.38 | 5.70 | 5.86 | 0.227 | 0.227 | 146 | 144 |
| Rice husk Si500 | 0.025 | 0.028 | 44 | 36 | 3.47 | 3.56 | 1.61 | 1.84 | 6.40 | 5.74 | 0.278 | 0.237 | 220 | 232 |
| CD (0.05) | 0.003 | | 5.0 | | 0.78 | | 0.22 | | 0.65 | | 0.032 | | 47 | |

**Table 33. Effects of Treatments on nutrient ratios of rice at maximum tillering**

| Treatments | N/P | N/K | N/Fe | N/Mn | N/ $SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/ $SiO_2$ | Fe/ $SiO_2$ | Mn/ $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 6.48 | 0.80 | 4.5 | 167 | 1.03 | 0.125 | 0.70 | 26.1 | 0.162 | 5.6 | 211 | 1.29 | 0.232 | 0.0062 |
| Rest | 6.71 | 0.89 | 6.6 | 202 | 0.94 | 0.133 | 0.99 | 30.3 | 0.141 | 7.6 | 227 | 1.06 | 0.145 | 0.0048 |
| CD (0.05) | NS | 0.07 | 0.9 | 26 | 0.07 | NS | 0.13 | NS | 0.014 | 1.3 | NS | 0.09 | 0.021 | 0.0007 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 6.38 | 0.95 | 6.5 | 234 | 1.00 | 0.149 | 1.02 | 36.5 | 0.156 | 7.0 | 245 | 1.05 | 0.156 | 0.0044 |
| Fine silica | 6.74 | 0.85 | 6.5 | 184 | 0.89 | 0.126 | 0.97 | 27.5 | 0.133 | 7.8 | 219 | 1.05 | 0.139 | 0.0049 |
| Rice husk | 7.01 | 0.87 | 6.8 | 187 | 0.94 | 0.124 | 0.99 | 26.9 | 0.133 | 8.0 | 218 | 1.08 | 0.140 | 0.0050 |
| CD (0.05) | 0.37 | 0.04 | NS | 18 | 0.05 | 0.008 | NS | 3.3 | 0.010 | NS | NS | NS | NS | 0.0005 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 6.41 | 0.85 | 6.9 | 197 | 0.92 | 0.132 | 1.09 | 30.6 | 0.143 | 8.3 | 232 | 1.09 | 0.134 | 0.0048 |
| $Si_{500}$ | 7.01 | 0.93 | 6.3 | 207 | 0.96 | 0.135 | 0.90 | 30.0 | 0.139 | 6.9 | 222 | 1.04 | 0.156 | 0.0048 |
| CD (0.05) | 0.30 | 0.03 | 0.5 | NS | NS | NS | 0.07 | NS | NS | 0.7 | NS | 0.05 | 0.012 | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 6.37 | 0.84 | 6.3 | 187 | 0.80 | 0.132 | 0.99 | 29.5 | 0.126 | 7.7 | 225 | 0.96 | 0.130 | 0.0043 |
| $K_{70}$ | 7.05 | 0.94 | 7.0 | 216 | 1.09 | 0.134 | 1.00 | 31.2 | 0.155 | 7.5 | 229 | 1.16 | 0.159 | 0.0052 |
| CD (0.05) | 0.30 | 0.03 | 0.5 | 15 | 0.04 | NS | NS | NS | 0.009 | NS | NS | 0.05 | 0.012 | 0.0004 |

The effect of different sources of silica on N/P, N/K, N/Mn, N/$SiO_2$, P/K, P/Mn, P/$SiO_2$ and Mn/$SiO_2$ ratios were significant.

Increasing the level of silica from 250 kg to 500 kg $ha^{-1}$ significantly influenced the N/P, N/K, N/Fe, F/Fe, K/Fe, K/$SiO_2$ and Fe/$SiO_2$ nutrient ratios.

N/P, N/K, N/Fe, N/Mn, N/$SiO_2$, P/$SiO_2$, K/$SiO_2$, Fe/$SiO_2$ and Mn/$SiO_2$ ratios were appreciably influenced by levels of K.

4.1.9 Effects of treatments on nutrient ratios at panicle initation (Table 34)

As compared to control, the ratios of N/P, N/Fe, N/Mn, N/$SiO_2$, P/Mn, P/$SiO_2$, K/Fe, K/Mn, K/$SiO_2$ and Fe/$SiO_2$ were found to be wider.

Sources of silica significantly influenced all the nutrient ratios except N/P, N/Mn and K/Fe ratios.

Application of higher levels of silica had widened the nutrient ratios of N/P, N/K, N/Mn, N/$SiO_2$, P/$SiO_2$ and Fe/$SiO_2$ by 4.2, 7.0, 8.1, 9.3, 6.4 and 10.8 per cent, respectively.

Increasing the level of K from 52.5 kg to 70 kg $ha^{-1}$ had significant effect on N/Fe, P/Fe, K/Fe, K/$SiO_2$, Fe/$SiO_2$ and Mn/$SiO_2$ ratios.

4.1.10 Effects of treatments on nutrient ratios at flowering (Table.35)

Applied treatments had significant effect on N/P, N/K, N/Fe, P/Fe, P/Mn, P/$SiO_2$,.K/Fe and K/$SiO_2$, over control, at flowering stage.

The sources of silica showed significant variation on N/$SiO_2$, P/$SiO_2$, K/$SiO_2$, Fe/$SiO_2$ and Mn/$SiO_2$ ratios.

The levels of silica influenced all the ratios except N/Mn, P/$SiO_2$ and Fe/$SiO_2$. In case of levels of K, the effect was confined to P/Fe, P/$SiO_2$, K/Fe and K/Mn.

**Table 34. Effects of Treatments on nutrient ratios of rice at panicle initiation**

| Treatments | N/P | N/K | N/Fe | N/Mn | N/ $SiO_2$ | P/K | P/Fe | P/Mn | P/ $SiO_2$ | K/Fe | K/Mn | K/ $SiO_2$ | Fe/ $SiO_2$ | Mn/ $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 5.80 | 0.801 | 15.1 | 149 | 0.69 | 0.139 | 0.66 | 25.9 | 0.119 | 4.8 | 187 | 0.86 | 0.181 | 0.0046 |
| Rest | 6.30 | 0.816 | 20.5 | 206 | 1.01 | 0.129 | 0.73 | 32.8 | 0.162 | 5.7 | 255 | 1.24 | 0.223 | 0.0050 |
| CD (0.05) | 0.46 | NS | 1.7 | 24 | 0.08 | NS | NS | 4.5 | 0.017 | 0.7 | 40 | 0.13 | 0.026 | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 6.17 | 0.859 | 19.4 | 211 | 1.33 | 0.132 | 0.80 | 34.3 | 0.217 | 5.7 | 247 | 1.57 | 0.274 | 0.0065 |
| Fine silica | 6.47 | 0.814 | 16.9 | 196 | 0.90 | 0.126 | 0.69 | 30.3 | 0.140 | 5.5 | 242 | 1.11 | 0.210 | 0.0046 |
| Rice husk | 6.27 | 0.774 | 17.0 | 211 | 0.81 | 0.124 | 0.71 | 33.8 | 0.128 | 5.7 | 277 | 1.04 | 0.186 | 0.0039 |
| CD (0.05) | NS | 0.043 | 1.1 | NS | 0.06 | 0.07 | 0.06 | 2.5 | 0.012 | NS | 22 | 0.09 | 0.018 | 0.0005 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 6.17 | 0.788 | 18.7 | 198 | 0.97 | 0.128 | 0.76 | 32.2 | 0.157 | 6.0 | 254 | 1.22 | 0.212 | 0.0050 |
| $Si_{500}$ | 6.43 | 0.843 | 16.9 | 214 | 1.06 | 0.131 | 0.71 | 33.4 | 0.167 | 5.4 | 256 | 1.26 | 0.235 | 0.0050 |
| CD (0.05) | 0.26 | 0.035 | 0.9 | 14 | 0.05 | NS | NS | NS | 0.01 | 0.4 | NS | NS | 0.014 | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 6.28 | 0.804 | 17.1 | 203 | 1.03 | 0.128 | 0.70 | 32.4 | 0.166 | 5.4 | 254 | 1.28 | 0.234 | 0.0052 |
| $K_{70}$ | 6.32 | 0.828 | 18.5 | 210 | 1.00 | 0.131 | 0.76 | 33.3 | 0.158 | 5.9 | 256 | 1.20 | 0.213 | 0.0048 |
| CD (0.05) | NS | NS | 0.9 | NS | NS | NS | 0.05 | NS | NS | 0.4 | NS | 0.07 | 0.014 | 0.0004 |

**Table 35. Effects of Treatments on nutrient ratios of rice at flowering**

| Treatments | N/P | N/K | N/Fe | N/Mn | N/ $SiO_2$ | P/K | P/Fe | P/Mn | P/ $SiO_2$ | K/Fe | K/Mn | K/ $SiO_2$ | Fe/ $SiO_2$ | Mn/ $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 6.70 | 1.06 | 7.4 | 73.4 | 0.325 | 0.160 | 1.12 | 11.1 | 0.049 | 6.98 | 69.1 | 0.307 | 0.044 | 0.0044 |
| Rest | 5.75 | 0.93 | 8.7 | 72.6 | 0.323 | 0.161 | 1.51 | 12.8 | 0.056 | 9.42 | 79.0 | 0.350 | 0.038 | 0.0045 |
| CD (0.05) | 0.79 | 0.12 | 1.1 | NS | NS | NS | 0.15 | 1.4 | 0.006 | 0.78 | NS | 0.039 | NS | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 5.70 | 0.90 | 8.4 | 72.3 | 0.278 | 0.157 | 1.48 | 12.8 | 0.049 | 9.38 | 80.9 | 0.310 | 0.033 | 0.0040 |
| Fine silica | 5.93 | 0.98 | 9.1 | 74.4 | 0.364 | 0.166 | 1.54 | 12.6 | 0.063 | 9.38 | 76.1 | 0.374 | 0.041 | 0.0050 |
| Rice husk | 5.62 | 0.90 | 8.6 | 71.2 | 0.327 | 0.161 | 1.52 | 12.8 | 0.058 | 9.51 | 80.1 | 0.365 | 0.039 | 0.0046 |
| CD (0.05) | NS | NS | NS | NS | 0.018 | NS | NS | NS | 0.004 | NS | NS | 0.026 | 0.003 | 0.0002 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 6.13 | 0.96 | 9.6 | 70.8 | 0.351 | 0.157 | 1.56 | 11.6 | 0.058 | 10.01 | 73.9 | 0.367 | 0.037 | 0.0050 |
| $Si_{500}$ | 5.37 | 0.89 | 7.8 | 74.4 | 0.295 | 0.166 | 1.46 | 13.9 | 0.055 | 8.83 | 84.2 | 0.332 | 0.039 | 0.0041 |
| CD (0.05) | 0.44 | NS | 0.6 | NS | 0.014 | 0.007 | 0.08 | 0.8 | NS | 0.43 | 5.6 | 0.022 | NS | 0.0002 |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 5.82 | 0.95 | 8.5 | 72.2 | 0.319 | 0.164 | 1.46 | 12.4 | 0.054 | 8.96 | 76.0 | 0.335 | 0.038 | 0.0044 |
| $K_{70}$ | 5.69 | 0.90 | 8.9 | 73.0 | 0.327 | 0.159 | 1.57 | 13.1 | 0.058 | 9.88 | 82.1 | 0.365 | 0.038 | 0.0046 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 0.08 | NS | 0.003 | 0.43 | 5.6 | NS | NS | NS |

4.1.11 Effects of treatments on nutrient ratios of straw at harvest (Table 36)

Compared to control, the applied treatments narrowed the N/P, N/K and $N/SiO_2$ ratios but widened K/Mn ratio.

Application of sodium silicate widened the ratios of N/Fe, N/Mn, P/Fe, P/Mn, K/Fe and K/Mn and narrowed P/Si, K/Si, Fe/Si and $Mn/SiO_2$ over the other two sources.

Application of 500 kg Si $ha^{-1}$ narrowed down the ratios of $P/SiO_2$, $K/SiO_2$, $Fe/SiO_2$ and $Mn/SiO_2$ by 11.5, 5.3, 6.7 and 5.9 per cent respectively, as compared to the lower levels of 250 kg $ha^{-1}$. But higher level of K widened the ratios of P/K, P/Fe and P/Mn over lower level of K.

4.1.12 Effects of treatments on nutrient ratios of grain at harvest (Table 37)

Application of different sources and levels of silica and levels of K significantly influenced the N/K, N/Fe and P/Fe ratios only.

Comparison of three sources of silica showed that application of sodium silicate widened the nutrient ratios of N/Mn, P/K, P/Fe and P/Mn, over the other two sources.

Increased levels of silica had significant effect on N/Mn and P/Mn only. But increased levels of K had no significant effect on any of the nutrient ratios.

4.1.13 Effects of treatments on pest and disease incidence at panicle initiation stage (Table 38)

Compared to control the general treatment effect significantly reduced the incidence of leaf roller, stem borer and gall midge by 56.7, 70.0 and 41.0 per cent respectively. However, the treatments had no effect on the incidence of sheath blight.

**Table 36. Effects of Treatments on nutrient ratios of straw at harvest**

| Treatments | N/P | N/K | N/Fe | N/Mn | N/ $SiO_2$ | P/K | P/Fe | P/Mn | P/ $SiO_2$ | K/Fe | K/Mn | K/ $SiO_2$ | Fe/ $SiO_2$ | Mn/ $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 9.71 | 0.56 | 7.9 | 13.3 | 0.224 | 0.058 | 0.80 | 1.4 | 0.023 | 13.9 | 23.7 | 0.402 | 0.029 | 0.017 |
| Rest | 7.60 | 0.44 | 6.6 | 11.4 | 0.185 | 0.059 | 0.88 | 1.5 | 0.024 | 15.1 | 26.2 | 0.427 | 0.029 | 0.017 |
| CD (0.05) | 1.69 | 0.11 | NS | NS | 0.039 | NS | NS | NS | NS | NS | 2.9 | NS | NS | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 8.04 | 0.47 | 7.8 | 13.2 | 0.177 | 0.060 | 0.99 | 1.7 | 0.022 | 16.5 | 27.1 | 0.381 | 0.023 | 0.014 |
| Fine silica | 7.39 | 0.45 | 6.1 | 10.8 | 0.184 | 0.062 | 0.83 | 1.5 | 0.025 | 13.8 | 24.3 | 0.415 | 0.030 | 0.017 |
| Rice husk | 7.36 | 0.39 | 5.9 | 10.2 | 0.193 | 0.055 | 0.81 | 1.4 | 0.026 | 14.9 | 26.2 | 0.485 | 0.033 | 0.019 |
| CD (0.05) | NS | NS | 1.0 | 1.7 | NS | NS | 0.07 | 0.1 | 0.001 | 1.1 | 1.5 | 0.022 | 0.001 | 0.0008 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 7.30 | 0.44 | 6.4 | 10.9 | 0.188 | 0.059 | 0.88 | 1.5 | 0.026 | 15.0 | 25.7 | 0.438 | 0.030 | 0.017 |
| $Si_{500}$ | 7.89 | 0.45 | 6.8 | 11.9 | 0.182 | 0.058 | 0.88 | 1.6 | 0.023 | 15.2 | 26.7 | 0.415 | 0.028 | 0.016 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | 0.001 | NS | NS | 0.018 | 0.001 | 0.0007 |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 7.72 | 0.42 | 6.3 | 11.0 | 0.181 | 0.056 | 0.82 | 1.5 | 0.024 | 15.0 | 26.5 | 0.437 | 0.029 | 0.017 |
| $K_{70}$ | 7.47 | 0.45 | 6.9 | 11.9 | 0.189 | 0.062 | 0.93 | 1.6 | 0.025 | 15.2 | 25.9 | 0.418 | 0.028 | 0.017 |
| CD (0.05) | NS | NS | NS | NS | NS | 0.004 | 0.05 | 0.1 | NS | NS | NS | 0.018 | NS | NS |

**Table 37. Effects of Treatments on nutrient ratios of grain at harvest**

| Treatments | N/P | N/K | N/Fe | N/Mn | N/ $SiO_2$ | P/K | P/Fe | P/Mn | P/ $SiO_2$ | K/Fe | K/Mn | K/ $SiO_2$ | Fe/ $SiO_2$ | Mn/ $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 7.96 | 1.79 | 31.4 | 266 | 0.46 | 0.23 | 4.0 | 33.8 | 0.058 | 17.6 | 95.7 | 0.257 | 0.015 | 0.0017 |
| Rest | 8.39 | 2.17 | 47.3 | 299 | 0.48 | 0.26 | 5.7 | 36.1 | 0.057 | 22.0 | 97.0 | 0.220 | 0.010 | 0.0017 |
| CD (0.05) | NS | 0.29 | 8.7 | NS | NS | NS | 1.3 | NS | NS | NS | NS | NS | NS | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 7.98 | 2.20 | 48.8 | 366 | 0.51 | 0.28 | 6.3 | 46.5 | 0.064 | 22.5 | 95.7 | 0.232 | 0.011 | 0.0015 |
| Fine silica | 8.37 | 2.22 | 49.6 | 252 | 0.46 | 0.27 | 6.0 | 30.3 | 0.055 | 22.6 | 96.5 | 0.210 | 0.009 | 0.0019 |
| Rice husk | 8.80 | 2.08 | 43.4 | 280 | 0.48 | 0.24 | 5.0 | 32.5 | 0.052 | 20.9 | 98.8 | 0.219 | 0.011 | 0.0016 |
| CD (0.05) | NS | NS | NS | 28 | NS | 0.02 | 0.9 | 4.8 | NS | NS | NS | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 8.38 | 2.17 | 46.1 | 267 | 0.49 | 0.26 | 5.6 | 32.2 | 0.058 | 21.5 | 95.7 | 0.220 | 0.011 | 0.0018 |
| $Si_{500}$ | 8.41 | 2.15 | 48.4 | 331 | 0.47 | 0.27 | 5.9 | 40.6 | 0.057 | 22.5 | 98.3 | 0.224 | 0.010 | 0.0015 |
| CD (0.05) | NS | NS | NS | 23 | NS | NS | NS | 3.9 | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 8.36 | 2.16 | 48.4 | 293 | 0.45 | 0.26 | 5.9 | 36.1 | 0.054 | 22.8 | 96.2 | 0.213 | 0.010 | 0.0016 |
| $K_{70}$ | 8.40 | 2.19 | 46.1 | 306 | 0.51 | 0.28 | 5.5 | 36.7 | 0.060 | 21.2 | 97.7 | 0.234 | 0.011 | 0.0017 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*a. Sources of silica*

Sources of silica failed to significantly influence the pest and disease incidence.

*b. Levels of silica*

Application of 500 kg Si $ha^{-1}$ reduced the incidence of leaf roller by 29.5 per cent and increased the incidence of gall midge by 33.3 per cent.

*c. Levels of K*

Increasing the level of K from 52.5 kg to 70 kg $ha^{-1}$ had no influence on pest and disease incidence.

4.1.14 Effects of treatments on post harvest status of available nutrients (Table 39)

The over all treatment effect showed significant reduction in the available status of Mg, Na, Fe, Mn and Zn and increased in the available status of P, as compared to control.

*a. Sources of Silica*

Sources of silica varied in their effect on the available status of organic carbon, P, Ca, Mg, Na, Fe, Mn and Zn. Sodium silicate was significantly inferior in the status of organic carbon, Na, Fe and Mn over the other two sources.

*b. Levels of silica*

Application of 500 kg Si $ha^{-1}$ significantly increased the available status of Fe, Mn and Zn by 5.9, 9.5 and 14.9 per cent respectively, over 250 kg Si $ha^{-1}$.

*c. Levels of K*

Higher dose of K decreased the status of organic carbon and Na but increased the status of Fe and Zn.

**Table 38. Effects of Treatments on pest and disease incidence at panicle initiation stage (per cent)**

| Treatments | Leaf roller | Stem borer | Gall midge | Sheath blight |
|---|---|---|---|---|
| Control | 66.7 | 0.77 | 0.83 | 100 |
| Rest | 28.9 | 0.23 | 0.49 | 100 |
| CD (0.05) | 11 | 0.15 | 0.23 | NS |
| *Sources of silica* | | | | |
| Sodium silicate | 30.0 | 0.23 | 0.52 | 100 |
| Fine silica | 29.2 | 0.21 | 0.54 | 100 |
| Rice husk | 27.5 | 0.23 | 0.41 | 100 |
| CD (0.05) | NS | NS | NS | NS |
| *Levels of silica* | | | | |
| $Si_{250}$ | 33.9 | 0.23 | 0.42 | 100 |
| $Si_{500}$ | 23.9 | 0.22 | 0.56 | 100 |
| CD (0.05) | 6.1 | NS | 0.13 | NS |
| *Levels of Potash* | | | | |
| $K_{52.5}$ | 30.0 | 0.23 | 0.52 | 100 |
| $K_{70}$ | 27.8 | 0.22 | 0.46 | 100 |
| CD (0.05) | NS | NS | NS | NS |

**Table 39. Effects of Treatments on post harvest status of available nutrients (kg ha$^{-1}$)**

| Treatments | Organic carbon | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.53 | 230 | 35 | 45 | 123 | 30.5 | 289 | 99 | 637 | 50 | 1.53 |
| Rest | 0.46 | 232 | 37 | 49 | 134 | 19.4 | 296 | 67 | 511 | 44 | 1.01 |
| CD (0.05) | NS | NS | 1.9 | NS | NS | 2.4 | NS | 8 | 49 | 3 | 0.10 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 0.27 | 231 | 39 | 50 | 131 | 20.3 | 295 | 58 | 477 | 42 | 1.02 |
| Fine silica | 0.56 | 234 | 35 | 48 | 126 | 18.1 | 296 | 65 | 530 | 43 | 1.01 |
| Rice husk | 0.55 | 230 | 37 | 50 | 146 | 19.9 | 297 | 78 | 525 | 47 | 1.00 |
| CD (0.05) | 0.05 | NS | 1.3 | NS | 13 | 1.6 | NS | 5 | 33 | 2 | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.47 | 227 | 37 | 50 | 131 | 18.7 | 298 | 69 | 496 | 42 | 0.94 |
| $Si_{500}$ | 0.45 | 236 | 37 | 49 | 138 | 20.1 | 294 | 65 | 525 | 46 | 1.08 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | 27 | 2 | 0.05 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 0.50 | 229 | 37 | 49 | 131 | 19.8 | 293 | 70 | 495 | 43 | 0.97 |
| $K_{70}$ | 0.42 | 234 | 37 | 50 | 138 | 19.0 | 298 | 64 | 526 | 45 | 1.05 |
| CD (0.05) | 0.04 | NS | NS | NS | NS | NS | NS | 4 | 27 | NS | 0.05 |

## 4.2 RESIDUAL CROP

The residual effect of the treatments, imposed during kharif crop on the succeeding rabi crop, in the presence and absence of potash application, is presented in this section.

### 4.2.1 Residual effects of treatments on growth attributes of rabi rice

#### 4.2.1.1 Residual effects of treatments on plant height (Table 40)

*a. Without potash*

Residual effect of none of the applied treatments was evident on plant height in the residual crop.

*b. With potash*

The general residual effect of the treatments increased the plant height at maximum tillering.

Residual effect of sources of silica was apparent in the presence of applied K at maximum tillering and flowering stages.

The residual effect of levels of silica significantly decreased the plant height at all the growth stages in the presence of K. Application of K to the residual crop decreased the plant height at flowering and harvesting stages.

#### 4.2.1.2 Residual effects of treatments on the number of total and productive tillers (Table 41)

*a. Without potash*

Residual effect of the treatments increased the number of total tillers and productive tillers over control at flowering and harvesting stage. The three factors forming the treatments however failed to individually influence the number of total and productive tillers.

**Table 40. Residual effects of treatments on height of rice**

| Treatments | Without potash<br>Plant height (cm) | | | | With potash<br>Plant height (cm) | | | |
|---|---|---|---|---|---|---|---|---|
| | MT | PI | Flg | HT | MT | PI | Flg | HT |
| Control | 28.5 | 33.6 | 57.0 | 57.0 | 28.3 | 32.9 | 57.7 | 56.8 |
| Rest | 29.0 | 33.2 | 56.5 | 56.5 | 29.8 | 34.7 | 58.5 | 57.1 |
| CD (0.05) | NS | NS | NS | NS | 1.2 | NS | NS | NS |
| *Forms of silica* | | | | | | | | |
| Sodium silicate | 28.2 | 32.8 | 56.3 | 56.3 | 29.8 | 35.1 | 59.4 | 58.0 |
| Fine silica | 29.4 | 33.6 | 56.7 | 56.7 | 29.0 | 35.2 | 57.1 | 56.1 |
| Rice husk | 29.4 | 33.1 | 56.6 | 56.6 | 30.6 | 35.0 | 58.9 | 57.1 |
| CD (0.05) | NS | NS | NS | NS | 0.9 | NS | 1.6 | NS |
| *Levels of silica* | | | | | | | | |
| $Si_{250}$ | 28.6 | 33.1 | 56.6 | 56.6 | 30.6 | 35.3 | 59.3 | 57.9 |
| $Si_{500}$ | 29.3 | 33.2 | 56.4 | 56.4 | 29.1 | 33.6 | 57.6 | 56.3 |
| CD (0.05) | NS | NS | NS | NS | 0.7 | 1.6 | 1.1 | 1.3 |
| *Levels of Potash* | | | | | | | | |
| $K_{52.5}$ | 28.7 | 33.0 | 55.9 | 55.9 | 29.9 | 34.7 | 59.1 | 58.0 |
| $K_{70}$ | 29.2 | 33.3 | 57.2 | 57.2 | 29.7 | 34.1 | 57.8 | 56.1 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 1.1 | 1.3 |

**Table 41. Residual effects of treatments on number of total and productive tillers**

| Treatments | Without potash | | | | | | With potash | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tillers per hill (No.) | | | | Productive tillers per hill (No.) | | Tillers per hill (No.) | | | | Productive tillers per hill (No.) | |
| | MT | PI | Flg | HT | Flg | HT | MT | PI | Flg | HT | Flg | HT |
| Control | 4.0 | 5.0 | 5.5 | 5.5 | 4.5 | 5.0 | 5.0 | 5.0 | 6.5 | 6.5 | 5.5 | 5.8 |
| Rest | 5.0 | 5.4 | 7.4 | 7.8 | 6.2 | 6.6 | 5.3 | 6.0 | 7.4 | 7.9 | 6.3 | 6.9 |
| CD (0.05) | NS | NS | 1.8 | 1.5 | 1.6 | 1.5 | NS | NS | NS | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | | |
| Sodium silicate | 4.8 | 5.4 | 7.4 | 7.9 | 6.1 | 6.5 | 5.0 | 6.0 | 7.9 | 8.8 | 6.5 | 7.3 |
| Fine silica | 5.1 | 5.3 | 7.0 | 7.5 | 6.1 | 6.6 | 5.0 | 6.0 | 6.9 | 7.1 | 5.9 | 6.4 |
| Rice husk | 5.1 | 5.5 | 7.8 | 7.9 | 6.4 | 6.6 | 5.8 | 5.9 | 7.4 | 7.8 | 6.6 | 7.1 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | 0.9 | 1.2 | NS | NS |
| *Levels of silica* | | | | | | | | | | | | |
| $Si_{250}$ | 4.8 | 5.1 | 7.3 | 7.5 | 6.1 | 6.4 | 5.4 | 6.1 | 7.5 | 7.8 | 6.3 | 7.2 |
| $Si_{500}$ | 5.1 | 5.6 | 7.4 | 8.0 | 6.3 | 6.8 | 5.1 | 5.8 | 7.3 | 7.9 | 6.3 | 6.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | |
| $K_{52.5}$ | 5.0 | 5.3 | 7.0 | 7.4 | 6.1 | 6.5 | 4.9 | 5.7 | 7.9 | 7.6 | 6.1 | 6.8 |
| $K_{70}$ | 5.0 | 5.5 | 7.8 | 8.1 | 6.3 | 6.7 | 5.6 | 6.3 | 7.8 | 8.2 | 6.6 | 7.1 |
| CD ( 0.05 ) | NS | NS | NS | NS | 6.3 | 6.3 | 0.6 | NS | 0.6 | NS | NS | NS |

*b. With potash*

The overall residual affect of the treatments was found to be non significant except in the case of total tillers at harvest.

Application of increased level of K in the second crop had significant effect on tiller count only at maximum tillering stage. The sources of silica showed variation on tiller count at flowering and harvesting stages only.

Current season application of K had no significant effect on the number of total and productive tillers except at maximum tillering stage.

4.2.1.3 Residual effects of treatments on dry matter production

*a. Without potash (Table 42)*

General residual effect of treatments during rabi season was apparent only on S/R at flowering. But the residual effect of the sources of silica was evident on shoot and root weight and S/R at panicle initiation and root weight and S/R at flowering.

Levels of silica had no significant residual effect on the components of dry matter production at any of the stages. The effect of levels of K was confined to panicle initiation stage.

*b. With potash (Table 43)*

The general effect of treatments had significant effect on S/R at maximum tillering and flowering, shoot and root weight and S/R at panicle initiation. Shoot and Root weight and S/R were significantly affected by the sources of silica at maximum tillering and panicle initiation stage.

Comparison of the residual effect of two levels of silica showed that application of 500 kg Si $ha^{-1}$ had increased S/R at maximum tillering and panicle initiation but decreased the shoot and root weight at panicle initiation and S/R at harvesting.

**Table 42. Residual effects of treatments on dry matter production (g / plant) (without potash)**

| Treatments | MaximumTillering | | | Panicle initiation | | | Flowering | | | Harvesting | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R |
| Control | 0.73 | 0.40 | 1.86 | 2.65 | 1.41 | 1.88 | 10.29 | 2.27 | 4.59 | 12.69 | 2.27 | 7.29 |
| Rest | 0.64 | 0.30 | 2.22 | 2.40 | 1.24 | 1.96 | 10.16 | 2.42 | 4.22 | 13.33 | 1.81 | 7.40 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | 0.35 | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | | |
| Sodium silicate | 0.66 | 0.33 | 2.07 | 2.24 | 1.11 | 2.03 | 10.45 | 2.42 | 4.15 | 13.33 | 1.36 | 7.58 |
| Fine silica | 0.64 | 0.28 | 2.30 | 2.63 | 1.40 | 1.89 | 9.67 | 2.19 | 4.42 | 13.51 | 1.84 | 7.36 |
| Rice husk | 0.62 | 0.28 | 2.30 | 2.34 | 1.20 | 1.95 | 10.35 | 2.54 | 4.08 | 13.16 | 1.83 | 7.26 |
| CD (0.05) | NS | NS | NS | 0.25 | 0.14 | 0.09 | NS | 0.24 | 0.28 | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | | |
| $Si_{250}$ | 0.65 | 0.30 | 2.19 | 2.39 | 1.24 | 1.95 | 10.20 | 2.47 | 4.13 | 13.34 | 1.82 | 7.38 |
| $Si_{500}$ | 0.63 | 0.29 | 2.25 | 2.41 | 1.24 | 1.96 | 10.11 | 2.36 | 4.30 | 13.33 | 1.80 | 7.42 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | |
| $K_{52.5}$ | 0.66 | 0.31 | 2.21 | 2.49 | 1.31 | 1.92 | 9.83 | 2.37 | 4.16 | 13.19 | 1.78 | 7.40 |
| $K_{70}$ | 0.62 | 0.28 | 2.23 | 2.31 | 1.17 | 1.99 | 10.49 | 2.46 | 4.28 | 13.47 | 1.84 | 7.40 |
| CD (0.05) | NS | NS | NS | 0.18 | 0.10 | 0.07 | NS | NS | NS | NS | NS | NS |

**Table 43. Residual effects of treatments on dry matter production (g / plant) (with potash)**

| Treatments | Maximum Tillering | | | Panicle initiation | | | Flowering | | | Harvesting | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R | Shoot | Root | S/R |
| Control | 0.69 | 0.31 | 2.23 | 2.36 | 1.22 | 1.93 | 11.37 | 2.13 | 5.4 | 11.66 | 2.23 | 6.12 |
| Rest | 0.67 | 0.34 | 1.97 | 2.82 | 1.71 | 1.74 | 10.68 | 2.41 | 4.5 | 12.74 | 1.97 | 6.25 |
| CD (0.05) | NS | NS | 0.17 | 0.25 | 0.19 | 0.14 | NS | NS | 0.5 | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | | |
| Sodium silicate | 0.65 | 0.36 | 1.80 | 2.66 | 1.42 | 1.89 | 9.94 | 2.49 | 4.0 | 13.24 | 2.06 | 6.39 |
| Fine silica | 0.61 | 0.31 | 2.01 | 2.58 | 1.57 | 1.76 | 11.33 | 2.34 | 4.9 | 12.21 | 1.97 | 6.12 |
| Rice husk | 0.76 | 0.36 | 2.09 | 3.22 | 2.14 | 1.57 | 10.77 | 2.40 | 4.5 | 12.78 | 2.05 | 6.25 |
| CD (0.05) | 0.11 | 0.05 | 0.13 | 0.20 | 0.15 | 0.11 | 1.15 | NS | NS | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | | |
| $Si_{250}$ | 0.65 | 0.34 | 1.89 | 3.04 | 1.88 | 1.69 | 10.81 | 2.35 | 4.6 | 13.15 | 2.02 | 6.51 |
| $Si_{500}$ | 0.70 | 0.34 | 2.04 | 2.60 | 1.54 | 1.79 | 10.54 | 2.47 | 4.3 | 12.34 | 2.04 | 6.00 |
| CD (0.05) | NS | NS | 0.09 | 0.14 | 0.10 | 0.08 | NS | NS | NS | NS | NS | 0.37 |
| *Levels of Potash* | | | | | | | | | | | | |
| $K_{52.5}$ | 0.68 | 0.35 | 1.92 | 2.71 | 1.57 | 1.78 | 10.41 | 2.40 | 4.4 | 12.90 | 2.04 | 6.33 |
| $K_{70}$ | 0.67 | 0.33 | 2.01 | 2.93 | 1.85 | 1.70 | 10.94 | 2.42 | 4.5 | 12.59 | 2.02 | 6.18 |
| CD (0.05) | NS | NS | NS | 0.14 | 0.10 | 0.08 | NS | NS | NS | NS | NS | NS |

Levels of K had significant effect on shoot and root weight and S/R at panicle initiation stage.

4.2.1.4 Two factor interaction effects on growth attributes of residual crop (Table 44 and 45)

*Interaction effects between sources and levels of silica*

*a. Without potash*

The residual effect of sodium silicate, with the increased level was confined to plant height at panicle initiation. Application of fine silica at 500 kg Si $ha^{-1}$ decreased the height at panicle intiation and root and shoot weight at flowering and harvesting, as compared to 250 kg Si $ha^{-1}$. Root weight at harvesting was increased by rice husk at 500 kg Si $ha^{-1}$.

*b. With potash*

Residual effect of sodium silicate at 500 kg Si $ha^{-1}$ had increased the number of tillers at harvesting but reduced the root and shoot weight at panicle initiation by 23.0 and 16.9 per cent, respectively. In case of fine silica higher level of application had decreased the plant height at flowering, root and shoot weight and S/R at panicle initiation and shoot weight and S/R at flowering and harvesting. With respect to rice husk the effect was confined to root weight at panicle initiation and shoot weight at flowering.

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

Residual effect of sodium silicate, with increasing levels of K, was apparent on tiller production at panicle initiation. With respect to fine silica the residual effect of 70 kg K $ha^{-1}$ decreased the root and shoot weight by 22.8 and 18.3 per cent. Combination of rice husk and levels of K had no residual effect on growth attributes.

**Table 44.Two factor interaction effects on growth attributes (without potash)**

| Treatments | Height at PI (cm) | | Root wt at Flg (g) | | Root wt at HT (g) | | Shoot wt at Flg (g) | | Shoot wt at HT (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 32.13 | 33.55 | 2.57 | 2.46 | 1.76 | 1.76 | 10.10 | 10.79 | 13.24 | 13.42 |
| Fine silica | 34.53 | 32.58 | 2.41 | 1.97 | 1.96 | 1.72 | 10.69 | 8.65 | 14.26 | 12.75 |
| Rice husk | 32.75 | 33.43 | 2.44 | 2.64 | 1.75 | 1.92 | 9.81 | 10.89 | 12.51 | 13.81 |
| CD (0.05) | 1.4 | | 0.29 | | 0.16 | | 1.3 | | 1.4 | |

| Treatments | Tillers per hill at PI (Nos.) | | Root wt at PI (g) | | Shoot wt at PI (g) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 7.0 | 8.8 | 1.16 | 1.05 | 2.31 | 2.16 |
| Fine silica | 8.0 | 7.0 | 1.58 | 1.22 | 2.90 | 2.37 |
| Rice husk | 7.3 | 8.5 | 1.18 | 1.23 | 2.27 | 2.42 |
| CD (0.05) | 1.5 | | 0.15 | | 0.31 | |

| Treatments | Height at PI (cm) | | Root wt at PI (g) | | Shoot wt at MT (g) | | S/R at PI | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 33.42 | 32.85 | 1.37 | 1.11 | 0.71 | 0.59 | 1.88 | 2.03 |
| Si500 | 32.65 | 33.72 | 1.24 | 1.23 | 0.61 | 0.65 | 1.96 | 1.96 |
| CD (0.05) | 1.16 | | 0.14 | | 0.11 | | 0.09 | |

Table 45. Two factor interaction effects on growth attributes (with potash)

| Treatments | Height at Flg (cm) | | Tillers per hill at HT (Nos.) | | Root wt at PI (g) | | Shoot wt at PI (g) | | Shoot wt at Flg (g) | | Shoot wt at HT (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 60.1 | 58.8 | 8.0 | 9.5 | 1.61 | 1.24 | 2.90 | 2.41 | 9.68 | 10.19 | 13.45 | 13.04 |
| Fine silica | 59.0 | 55.3 | 7.8 | 6.5 | 1.99 | 1.14 | 3.01 | 2.16 | 13.28 | 9.37 | 13.78 | 10.65 |
| Rice husk | 58.9 | 58.9 | 7.8 | 7.8 | 2.05 | 2.23 | 3.21 | 3.23 | 9.47 | 12.06 | 12.63 | 12.92 |
| CD (0.05) | 1.9 | | 1.4 | | 0.18 | | 0.24 | | 1.41 | | 1.78 | |

| Treatments | S/R at PI | | S/R at Flg | | S/R at HT | |
|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.81 | 1.96 | 4.00 | 3.99 | 6.25 | 6.53 |
| Fine silica | 1.62 | 1.90 | 5.38 | 4.34 | 6.74 | 5.49 |
| Rice husk | 1.63 | 1.51 | 4.45 | 4.58 | 6.53 | 5.98 |
| CD (0.05) | 0.14 | | 0.60 | | 0.64 | |

| Treatments | Height at MT (cm) | | Root wt at PI (g) | | Shoot wt at PI (g) | | Shoot wt at Flg (g) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 29.1 | 30.7 | 1.38 | 1.46 | 2.59 | 2.72 | 9.08 | 10.79 |
| Fine silica | 29.4 | 28.7 | 1.24 | 1.90 | 2.30 | 2.87 | 11.83 | 10.82 |
| Rice husk | 31.3 | 29.8 | 2.09 | 2.19 | 3.23 | 3.21 | 10.31 | 11.22 |
| CD (0.05) | 1.1 | | 0.18 | | 0.24 | | 1.41 | |

*b. With potash*

In respect of sodium silicate application of 70 kg $ha^{-1}$ of K increased the plant height at maximum tillering and shoot weight at flowering by 5.5 and 18.8 per cent, as compared to the lower dose. In this case of fine silica, increased level of K increased the root and shoot weight at panicle initiation by 53.2 and 24.8 per cent. Increasing the level of potash decreased the plant height at maximum tillering by 1.5 per cent, in respect of rice husk.

*Interaction between levels of silica and K (without potash)*

The effect of increasing levels of potash was evident on root weight and S/R at panicle initiation and shoot weight at maximum tillering at 250 kg Si $ha^{-1}$ level but not at 500 kg Si $ha^{-1}$.

4.2.2 Residual effects of treatments on yield and yield attributes

*a. Without potash (Table 46)*

The general residual effect had significant effect on grain yield and flag leaf length only.

Sources of silica had significant residual effect on flag leaf length while the level of silica had significant effect on flag leaf width.

Levels of K failed to show residual effect on any of the yield attributes.

*b. With potash (Table 47)*

The generalised residual effect had significantly increased the grain yield and grain:straw ratio by 12.8 and 28.0 per cent but reduced the straw yield and days to 50 per cent flowering by 9.8 and 4.5 per cent respectively. The flag leaf width was also increased.

Sources and levels of silica had significant effect on 1000 grain weight, grain and straw yield and chaff number.

**Table 46. Residual effects of treatments on yield characters of rice (without potash)**

| Treatments | 50% flowering (days) | Flag leaf width (cm) | Flag leaf length (cm) | Panicle length (cm) | Panicle weight (g) | Filled grains per panicle (Nos.) | Chaff per cent | 1000 grain wt(g) | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Grain straw ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 91.0 | 0.97 | 16.94 | 18.15 | 1.39 | 45.0 | 28.3 | 26.07 | 2681 | 3051 | 0.88 |
| Rest | 90.7 | 0.98 | 15.86 | 18.06 | 1.64 | 54.3 | 26.9 | 26.52 | 3252 | 3270 | 1.01 |
| CD (0.05) | NS | NS | 1.06 | NS | NS | NS | NS | NS | 523 | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 91.3 | 0.98 | 15.23 | 18.23 | 1.65 | 48.9 | 28.9 | 26.67 | 3366 | 3590 | 0.95 |
| Fine silica | 91.4 | 0.99 | 16.32 | 17.96 | 1.63 | 51.5 | 27.2 | 26.34 | 3115 | 3094 | 1.02 |
| Rice husk | 89.4 | 0.98 | 16.03 | 17.98 | 1.63 | 53.5 | 24.5 | 26.56 | 3274 | 3125 | 1.08 |
| CD (0.05) | NS | NS | 0.83 | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 91.1 | 0.96 | 15.59 | 17.91 | 1.60 | 52.3 | 25.9 | 26.55 | 3213 | 3241 | 1.03 |
| $Si_{500}$ | 90.3 | 1.01 | 16.13 | 18.20 | 1.67 | 50.3 | 27.8 | 26.49 | 3290 | 3299 | 1.01 |
| CD (0.05) | NS | 0.04 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 90.5 | 0.98 | 15.83 | 17.87 | 1.57 | 50.0 | 26.5 | 26.34 | 3206 | 3261 | 1.01 |
| $K_{70}$ | 90.8 | 0.98 | 15.89 | 18.24 | 1.70 | 52.6 | 27.3 | 26.71 | 3298 | 3278 | 1.03 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**Table 47. Residual effects of treatments on yield characters of rice (with potash)**

| Treatments | 50% flowering (days) | Flag leaf length (cm) | Flag leaf width (cm) | Panicle length (cm) | Panicle weight (g) | Filled grains per panicle (Nos.) | Chaff per cent | 1000 grain wt(g) | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Grain straw ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 91.5 | 13.35 | 0.90 | 17.6 | 1.46 | 51.5 | 20.9 | 26.71 | 2789 | 3721 | 0.75 |
| Rest | 87.4 | 16.38 | 0.99 | 18.1 | 1.66 | 53.3 | 24.7 | 26.69 | 3147 | 3356 | 0.96 |
| CD (0.05) | 1.5 | NS | 0.08 | NS | NS | NS | NS | NS | 195 | 80 | 0.11 |
| Forms of silica | | | | | | | | | | | |
| Sodium silicate | 87.4 | 17.07 | 1.02 | 17.9 | 1.70 | 54.9 | 21.1 | 27.34 | 3298 | 3261 | 1.03 |
| Fine silica | 88.4 | 14.72 | 0.95 | 18.2 | 1.57 | 50.6 | 26.2 | 26.25 | 3122 | 3636 | 0.86 |
| Rice husk | 86.4 | 17.34 | 1.00 | 18.3 | 1.71 | 54.3 | 26.7 | 26.49 | 3021 | 3170 | 0.98 |
| CD (0.05) | 1.2 | NS | NS | NS | NS | NS | 3.9 | 0.63 | 153 | 63 | 0.09 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 87.4 | 16.10 | 0.99 | 18.2 | 1.71 | 54.2 | 25.2 | 26.95 | 3254 | 3510 | 0.95 |
| $Si_{500}$ | 87.3 | 16.65 | 0.99 | 18.1 | 1.62 | 52.3 | 24.1 | 26.44 | 3039 | 3202 | 0.97 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | 0.44 | 108 | 44 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 87.2 | 17.08 | 0.99 | 18.4 | 1.78 | 57.4 | 22.5 | 26.58 | 3120 | 3270 | 0.97 |
| $K_{70}$ | 87.6 | 15.08 | 0.99 | 17.8 | 1.55 | 49.1 | 26.8 | 26.81 | 3173 | 3442 | 0.95 |
| CD (0.05) | NS | NS | NS | NS | 0.22 | 13.7 | 3.2 | NS | NS | 44 | NS |

Increased application of 70 kg K $ha^{-1}$ decreased the panicle weight and filled grains per panicle but increased the straw yield.

4.2.2.1 Two factor interaction effects on yield and yield attributes (with potash) (Table 48)

*Interaction between sources and levels of silica*

Interaction effect between sources and levels of silica showed that, irrespective of sources, increasing level of silica from 250 to 500 kg $ha^{-1}$ decreased the grain yield but the rate of decrease was maximum in fine silica. With respect to straw yield, sodium silicate and fine silica at 500 kg Si $ha^{-1}$ decreased the straw yield but rice husk increased the straw yield. Sodium silicate with higher level of silica increased the grain:straw ratio by 30.0 per cent whereas rice husk decreased the ratio by 27.1.

*Interaction between sources of silica and levels of K*

Application of higher levels of K significantly increased the straw yield by 6.0 and 12.1 per cent in the case of sodium silicate and rice husk whereas in the case of fine silica straw yield was decreased by 9.4 per cent and chaff number was increased by 41.4 per cent. Rice husk reduced the chaff number by 24.4 per cent at higher level of K.

*Interaction between levels of silica and K*

The effect of silica in increasing the straw yield was significantly affected by the level of K.

4.2.3 Residual effects of treatment on nutrient content at maximum tillering

*a. Without potash (Table 49)*

Compared to control, the general residual effect of the treatments had increased the P and Mg content by 26.6 and 10.4 per cent and reduced the Mn, Zn

**Table 48. Two factor interaction effects on yield and yield attributes (with potash)**

| Treatments | Grain yield (kg ha$^{-1}$) | | Straw yield (kg ha$^{-1}$) | | Grain straw ratio | |
|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 3318 | 3277 | 3723 | 2799 | 0.90 | 1.17 |
| Fine silica | 3414 | 2829 | 4136 | 3136 | 0.83 | 0.90 |
| Rice husk | 3031 | 3011 | 2670 | 3670 | 1.14 | 0.82 |
| CD (0.05) | 187 | | 77 | | 0.11 | |

| Treatments | Chaff per panicle (nos) | | Straw yield (kg ha$^{-1}$) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 13.3 | 16.0 | 3160 | 3362 |
| Fine silica | 14.5 | 20.5 | 3974 | 3599 |
| Rice husk | 22.5 | 17.0 | 2976 | 3384 |
| CD (0.05) | 5.5 | | 77 | |

| Treatments | Straw yield (kg ha$^{-1}$) | |
|---|---|---|
| | K52.5 | K70.0 |
| Si250 | 3395 | 3624 |
| Si500 | 3144 | 3259 |
| CD (0.05) | 63 | |

**Table 49. Residual effects of treatments on nutrient content of rice at MT (without potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 3.36 | 0.184 | 2.55 | 0.086 | 0.115 | 2271 | 0.83 | 3293 | 243 | 46.0 | 3.38 |
| Rest | 3.48 | 0.233 | 2.69 | 0.097 | 0.127 | 2013 | 0.79 | 3440 | 171 | 50.0 | 2.80 |
| CD (0.05) | NS | 0.025 | NS | NS | 0.011 | NS | NS | NS | 20 | 4.7 | 0.24 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 3.43 | 0.244 | 2.74 | 0.087 | 0.127 | 2000 | 0.75 | 2957 | 164 | 30.0 | 3.24 |
| Fine silica | 3.60 | 0.227 | 2.69 | 0.096 | 0.126 | 2164 | 0.80 | 3796 | 173 | 30.3 | 2.53 |
| Rice husk | 3.41 | 0.229 | 2.64 | 0.106 | 0.126 | 1874 | 0.81 | 3568 | 177 | 29.4 | 2.63 |
| CD (0.05) | 0.19 | NS | NS | NS | NS | NS | NS | 635 | NS | NS | 0.19 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 3.41 | 0.230 | 2.73 | 0.103 | 0.127 | 2017 | 0.75 | 3678 | 174 | 28.8 | 2.96 |
| $Si_{500}$ | 3.55 | 0.237 | 2.65 | 0.090 | 0.126 | 2008 | 0.82 | 3203 | 169 | 31.0 | 2.64 |
| CD (0.05) | 0.14 | NS | NS | NS | NS | NS | NS | 449 | NS | NS | 0.13 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 3.54 | 0.235 | 2.68 | 0.106 | 0.131 | 1985 | 0.76 | 3464 | 169 | 30.2 | 2.86 |
| $K_{70}$ | 3.42 | 0.231 | 2.69 | 0.088 | 0.128 | 2040 | 0.81 | 3416 | 174 | 29.6 | 2.74 |
| CD (0.05) | 0.14 | NS | NS | 0.016 | 0.006 | NS | NS | NS | NS | NS | NS |

and $SiO_2$ content by 29.6, 34.8 and 17.2 per cent respectively, at maximum tillering stage.

Sources of silica varied in their residual effect only on N and Fe content. Application of fine silica increased the N content over rice husk by 5.6 per cent and Fe content over sodium silicate by 28.4 per cent.

Enhancement in the level of silica had significant residual effect on N and Fe content only and the content of other nutrients remained unaffected.

Higher level of K significantly reduced the N and Ca contents.

*b. With potash (Table 50)*

The general residual effect of treatments had significantly increased P, K, Ca and $SiO_2$ contents by 10.2, 30.5, 32.6 and 59.2 per cent but decreased the Na and Fe content by 22.4 and 22.3 per cent over control.

Application of sodium silicate decreased the N, S, Fe and Mn content by 8.2, 11.1, 44.8 and 23.8 per cent and increased the P, Ca and $SiO_2$ content by 23.5, 14.3 and 73.0 per cent compared to fine silica. With respect to rice husk the increase of P and $SiO_2$ was 9.2 and 25.1 per cent and the decrease of N, Ca and S was 5.8, 24.5 and 14.5 per cent respectively.

Increasing level of silica significantly decreased the N and S content by 4.8 and 18.2 per cent and increased the Ca and Mg content by 10.1 and 16.5 per cent.

Levels of K had significant effect on Ca, Zn and $SiO_2$ contents.

**Table 50. Residual effects of treatments on nutrient content of rice at MT (with potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 3.47 | 0.225 | 2.20 | 0.086 | 0.099 | 1905 | 0.875 | 3627 | 157 | 32.0 | 1.69 |
| Rest | 3.43 | 0.248 | 2.87 | 0.114 | 0.111 | 1677 | 0.679 | 2819 | 147 | 25.7 | 2.69 |
| CD (0.05) | NS | 0.020 | 0.19 | 0.009 | NS | 170 | 0.130 | 276 | NS | 3.8 | 0.29 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 3.27 | 0.273 | 2.93 | 0.112 | 0.112 | 1527 | 0.675 | 2174 | 134 | 24.4 | 3.39 |
| Fine silica | 3.56 | 0.221 | 2.83 | 0.098 | 0.108 | 1718 | 0.744 | 3941 | 176 | 25.9 | 1.96 |
| Rice husk | 3.47 | 0.250 | 2.84 | 0.131 | 0.114 | 1785 | 0.619 | 2341 | 132 | 26.8 | 2.71 |
| CD (0.05) | 0.13 | 0.016 | NS | 0.007 | NS | 133 | 0.102 | 217 | 14 | NS | 0.23 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 3.52 | 0.253 | 2.88 | 0.108 | 0.103 | 1844 | 0.679 | 2854 | 145 | 24.7 | 2.63 |
| $Si_{500}$ | 3.35 | 0.243 | 2.85 | 0.119 | 0.120 | 1509 | 0.679 | 2783 | 149 | 26.7 | 2.74 |
| CD (0.05) | 0.09 | NS | NS | 0.005 | 0.007 | 94 | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 3.44 | 0.243 | 2.83 | 0.107 | 0.110 | 1687 | 0.675 | 2792 | 145 | 24.6 | 2.77 |
| $K_{70}$ | 3.43 | 0.253 | 2.90 | 0.120 | 0.112 | 1666 | 0.683 | 2845 | 149 | 26.8 | 2.60 |
| CD (0.05) | NS | NS | NS | 0.005 | NS | NS | NS | NS | NS | 2.1 | 0.16 |

4.2.3.1 Residual effects of treatments on nutrient uptake at maximum tillering

*a. Without potash (Table 51)*

As compared to control, the general residual effect of the treatments had significantly reduced the uptake of S, Mn, Zn and $SiO_2$ by 23.5, 41.5, 44.1 and 31.4 per cent respectively.

Among the sources of silica, sodium silicate recorded the highest uptake of $SiO_2$ followed by rice husk and fine silica. Uptake of other nutrients were unaffected by the sources of silica.

Application of 500 kg Si $ha^{-1}$ had significant residual effect on Fe uptake alone by reducing the uptake from 2.33 to 1.94 kg $ha^{-1}$. The increasing level of K had significant effect on the uptake of Ca, Mg and S.

*b. With potash (Table 52)*

The general residual effect of the treatments significantly increased the uptake of K, Ca and $SiO_2$ by 32.7, 34.5 and 62.8 per cent, as compared to control but reduced the Na and Fe uptake by 22.0 and 22.2 per cent.

When compared to fine silica sodium silicate increased the P and Ca uptake by 35.3 and 25.0 per cent and decreased the Fe and Mn uptake by 39.9 and 16.7 per cent with respect to rice husk the increase in uptake of N, Ca, S, Zn and $SiO_2$ were to the tune of 18.6, 32.0, 30.0, 25.0 and 55.4 per cent respectively.

Levels of silica had significantly affected the uptake of Ca, Mg and S only.

Levels of K significantly increased the Ca uptake alone by 12.3 per cent.

**Table 51. Residual effects of treatments on nutrient uptake (kg $ha^{-1}$) of rice at MT (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 25.4 | 1.4 | 19.3 | 0.645 | 0.866 | 1.7 | 6.1 | 2.50 | 0.183 | 0.034 | 25.5 |
| Rest | 22.0 | 1.5 | 17.0 | 0.611 | 0.795 | 1.3 | 4.9 | 2.13 | 0.107 | 0.019 | 17.5 |
| CD (0.05) | NS | NS | NS | NS | NS | 0.34 | NS | NS | 0.030 | 0.005 | 6.0 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 23.1 | 1.6 | 18.3 | 0.594 | 0.846 | 1.3 | 5.0 | 1.93 | 0.108 | 0.019 | 21.4 |
| Fine silica | 22.0 | 1.4 | 16.6 | 0.590 | 0.768 | 1.3 | 4.8 | 2.35 | 0.106 | 0.019 | 15.3 |
| Rice husk | 20.9 | 1.4 | 16.1 | 0.651 | 0.770 | 1.1 | 4.9 | 2.12 | 0.108 | 0.018 | 15.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 4.7 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 21.8 | 1.5 | 17.4 | 0.660 | 0.812 | 1.3 | 4.8 | 2.33 | 0.111 | 0.018 | 18.6 |
| $Si_{500}$ | 22.2 | 1.5 | 16.6 | 0.562 | 0.777 | 1.2 | 5.1 | 1.94 | 0.104 | 0.019 | 16.4 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | 0.36 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 23.3 | 1.6 | 17.6 | 0.694 | 0.860 | 1.3 | 5.0 | 2.21 | 0.110 | 0.020 | 18.8 |
| $K_{70}$ | 20.7 | 1.4 | 16.3 | 0.529 | 0.729 | 1.2 | 4.9 | 2.06 | 0.105 | 0.018 | 16.1 |
| CD (0.05) | NS | NS | NS | 0.148 | 0.127 | NS | NS | NS | NS | NS | NS |

**Table 52. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of rice at MT (with potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 23.2 | 1.48 | 14.7 | 0.58 | 0.67 | 1.3 | 5.9 | 2.43 | 0.105 | 0.022 | 11.3 |
| Rest | 23.4 | 1.69 | 19.5 | 0.78 | 0.76 | 1.1 | 4.6 | 1.89 | 0.099 | 0.017 | 18.4 |
| CD (0.05) | NS | NS | 4.0 | 0.14 | NS | NS | 1.2 | 0.43 | NS | NS | 5.1 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 22.1 | 1.84 | 19.8 | 0.75 | 0.76 | 1.0 | 4.5 | 1.46 | 0.090 | 0.016 | 13.0 |
| Fine silica | 21.9 | 1.36 | 17.4 | 0.60 | 0.66 | 1.1 | 4.6 | 2.43 | 0.108 | 0.016 | 11.9 |
| Rice husk | 26.2 | 1.88 | 21.4 | 0.99 | 0.87 | 1.3 | 4.7 | 1.79 | 0.100 | 0.020 | 20.2 |
| CD (0.05) | 3.6 | 0.23 | 3.1 | 0.11 | 0.16 | 0.2 | NS | 0.34 | 0.015 | 0.004 | 4.0 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 23.2 | 1.66 | 19.0 | 0.72 | 0.68 | 1.3 | 4.6 | 1.87 | 0.095 | 0.016 | 17.4 |
| $Si_{500}$ | 23.6 | 1.72 | 20.0 | 0.84 | 0.85 | 1.1 | 4.7 | 1.91 | 0.103 | 0.019 | 19.4 |
| CD (0.05) | NS | NS | NS | 0.08 | 0.11 | 0.1 | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 23.6 | 1.68 | 19.6 | 0.73 | 0.77 | 1.2 | 4.6 | 1.89 | 0.098 | 0.017 | 19.4 |
| $K_{70}$ | 23.2 | 1.71 | 19.5 | 0.82 | 0.76 | 1.1 | 4.5 | 1.91 | 0.098 | 0.018 | 17.4 |
| CD (0.05) | NS | NS | NS | 0.08 | NS | NS | NS | NS | NS | NS | NS |

### 4.2.3.2 Two factor interaction effect on nutrient content of rice at maximum tillering (Table 53 and 54)

*Interaction between sources and levels of silica*

*a. Without potash*

Residual effect of the higher dose of silica as sodium silicate significantly increased the N, P and Zn content by 13.0, 13.1 and 50.0 per cent and reduces the Fe and Mn content by 37.2 and 15.7 per cent over the lower dose. However residual effect of fine silica at the higher dose reduced the contents of P and K and increased the content of Na significantly. The residual effect of rice husk at the two doses was confined to P content only.

*b. With potash*

Residual effect of the increased dose of silica as sodium silicate increased the P, K and Mg content by 11.6, 17.0 and 35.3 per cent and reduced the Mn and $SiO_2$ content by 18.9 and 10.9 per cent. Higher dose of silica as fine silica reduced the P content. Increased dose of silica as rice husk increased the contents of Ca, Mn and $SiO_2$ by 22.9, 50.0 and 20.8 per cent respectively.

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

Among the three sources only rice husk had significant combined residual effect with levels of K on Zn and $SiO_2$ content.

*b. With potash*

Combined residual effect of sources of silica and levels of K showed that application of sodium silicate with 70 kg K $ha^{-1}$ increased the P and Zn content by 7.6 and 45.0 per cent and decreased the N and $SiO_2$ content by 6.2 and 7.9 per cent over 52.5 kg K $ha^{-1}$. But the interaction effect of fine silica with levels of K was confined to N and Mn content only. With respect to rice husk the P content was increased and $SiO_2$ content was reduced by 12.8 and 15.7 per cent respectively with the increasing dose of K.

**Table 53. Two factor interaction effects on nutrient content of rice at maximum tillering (without potash)**

| Treatments | N (%) | | P (%) | | K (%) | | Na (%) | |
|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 3.22 | 3.64 | 0.229 | 0.259 | 2.70 | 2.80 | 0.713 | 0.788 |
| Fine silica | 3.57 | 3.64 | 0.245 | 0.209 | 2.90 | 2.50 | 0.675 | 0.925 |
| Rice husk | 3.45 | 3.38 | 0.216 | 0.243 | 2.70 | 2.60 | 0.863 | 0.750 |
| CD (0.05) | 0.22 | | 0.027 | | 0.17 | | 0.162 | |

| Treatments | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 3634 | 2281 | 178 | 150 | 0.016 | 0.024 |
| Fine silica | 4083 | 3509 | 166 | 181 | 0.019 | 0.018 |
| Rice husk | 3316 | 3820 | 179 | 175 | 0.020 | 0.016 |
| CD (0.05) | 778 | | 19 | | 0.005 | |

| Treatments | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 30.5 | 29.5 | 3.36 | 3.12 |
| Fine silica | 28.3 | 32.3 | 2.46 | 2.61 |
| Rice husk | 31.8 | 27.0 | 2.76 | 2.50 |
| CD (0.05) | 4.3 | | 0.23 | |

| Treatments | N (%) | | Zn (ppm) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 3.61 | 3.22 | 26.8 | 30.7 |
| Si500 | 3.48 | 3.63 | 33.5 | 28.5 |
| CD (0.05) | 0.18 | | 3.7 | |

**Table 54.Two factor interaction effects on nutrient content of rice at maximum tillering (with potash)**

| Treatments | P (%) | | K (%) | | Ca (%) | | Mg (%) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.258 | 0.288 | 2.70 | 3.16 | 0.114 | 0.110 | 0.095 | 0.129 | 148 | 120 | 3.58 | 3.19 |
| Fine silica | 0.248 | 0.195 | 2.99 | 2.66 | 0.094 | 0.101 | 0.103 | 0.112 | 183 | 169 | 1.84 | 2.08 |
| Rice husk | 0.255 | 0.245 | 2.94 | 2.74 | 0.118 | 0.145 | 0.109 | 0.119 | 106 | 159 | 2.45 | 2.96 |
| CD (0.05) | 0.019 | | 0.37 | | 0.008 | | 0.011 | | 17 | | 0.28 | |

| Treatments | N (%) | | P (%) | | Mg (%) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 3.38 | 3.17 | 0.263 | 0.283 | 0.107 | 0.117 | 136 | 132 | 20 | 29 | 3.53 | 3.25 |
| Fine silica | 3.66 | 3.47 | 0.233 | 0.210 | 0.114 | 0.101 | 164 | 188 | 26 | 26 | 1.85 | 2.07 |
| Rice husk | 3.52 | 3.41 | 0.235 | 0.265 | 0.110 | 0.118 | 136 | 128 | 28 | 25 | 2.94 | 2.48 |
| CD (0.05) | 0.15 | | 0.019 | | 0.011 | | 17 | | 4 | | 0.28 | |

| Treatments | Mg (%) | | Fe (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.106 | 0.099 | 2913 | 2795 | 2.57 | 2.68 |
| Si500 | 0.115 | 0.125 | 2672 | 2894 | 2.97 | 2.51 |
| CD (0.05) | 0.009 | | 217 | | 0.23 | |

*Interaction between levels of silica and K*

*a. Without potash*

At 250 kg Si ha$^{-1}$, higher dose of K decreased the N content by 10.8 per cent and increased the Zn content by 14.6 per cent. At 500 kg Si ha$^{-1}$, Zn content alone was reduced by 14.9 per cent.

*b. With potash*

A scrutiny of the data revealed that only at higher level of silica, the increasing level of K had significant effect on Mg, Fe and $SiO_2$ content at maximum tillering.

4.2.4 Residual effects of treatments on nutrient content at panicle initiation

*a. Without potash (Table 55)*

As compared to control, the general residual effect of the treatments significantly increased the contents of N, Ca, S, Fe and $SiO_2$ and reduced the contents of Mg, Na and Mn.

Among the three sources of silica, fine silica recorded highest content of N, P, Ca and Mg followed by rice husk and sodium silicate. But in the case of Fe content rice husk recorded the higher content followed by sodium silicate and fine silica.

Residual effect of 500 kg Si ha$^{-1}$ increased the Ca and $SiO_2$ content and reduced the Fe content by 12.9, 6.3 and 10.9 per cent respectively, over the lower dose. Residual effect of the levels of K was confined to Ca content alone.

*b. With potash (Table 56)*

The general residual effect of the treatments significantly increased the P, K, Mg, S and Fe content and reduced the Ca, Na and Mn content over control.

**Table 55. Residual effects of treatments on nutrient content of rice at PI (without potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 1.79 | 0.159 | 2.03 | 0.138 | 0.154 | 1604 | 1.18 | 1825 | 149 | 25.0 | 3.31 |
| Rest | 1.96 | 0.163 | 2.07 | 0.149 | 0.136 | 1899 | 0.87 | 2055 | 128 | 27.2 | 4.93 |
| CD (0.05) | 0.11 | NS | NS | 0.009 | 0.015 | 224 | 0.11 | 79 | 19 | NS | 0.46 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 1.89 | 0.150 | 2.01 | 0.137 | 0.132 | 1991 | 0.91 | 2052 | 129 | 27.6 | 4.96 |
| Fine silica | 2.03 | 0.177 | 2.09 | 0.162 | 0.143 | 1844 | 0.86 | 1986 | 129 | 26.4 | 4.98 |
| Rice husk | 1.96 | 0.163 | 2.10 | 0.148 | 0.132 | 1863 | 0.84 | 2128 | 127 | 27.6 | 4.85 |
| CD (0.05) | 0.03 | 0.004 | NS | 0.007 | 0.011 | NS | NS | 129 | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.90 | 0.162 | 2.10 | 0.140 | 0.136 | 1939 | 0.85 | 2174 | 131 | 26.9 | 4.78 |
| $Si_{500}$ | 2.02 | 0.164 | 2.03 | 0.158 | 0.135 | 1859 | 0.88 | 1937 | 126 | 27.5 | 5.08 |
| CD (0.05) | 0.09 | NS | NS | 0.005 | NS | NS | NS | 96 | NS | NS | 0.26 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.91 | 0.166 | 2.03 | 0.145 | 0.133 | 1936 | 0.86 | 2078 | 131 | 27.7 | 4.85 |
| $K_{70}$ | 2.01 | 0.160 | 2.10 | 0.153 | 0.138 | 1863 | 0.88 | 2033 | 126 | 26.8 | 5.01 |
| CD (0.05) | 0.09 | NS | NS | 0.005 | NS | NS | NS | NS | NS | NS | NS |

**Table 56. Residual effects of treatments on nutrient content of rice at PI (with potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 2.0 | 0.155 | 2.10 | 0.152 | 0.076 | 1500 | 0.88 | 1680 | 199 | 32 | 2.64 |
| Rest | 1.9 | 0.199 | 2.61 | 0.139 | 0.106 | 1664 | 0.60 | 2053 | 141 | 29 | 2.56 |
| CD (0.05) | NS | 0.015 | 0.14 | 0.009 | 0.014 | 110 | 0.10 | 324 | 24 | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 1.99 | 0.176 | 2.65 | 0.137 | 0.108 | 1716 | 0.67 | 2094 | 137 | 28 | 2.64 |
| Fine silica | 1.74 | 0.168 | 2.58 | 0.135 | 0.105 | 1641 | 0.59 | 1859 | 143 | 29 | 2.25 |
| Rice husk | 1.97 | 0.185 | 2.60 | 0.144 | 0.106 | 1634 | 0.54 | 2205 | 145 | 30 | 2.81 |
| CD (0.05) | 0.08 | 0.012 | NS | 0.007 | NS | NS | 0.08 | 254 | NS | NS | 0.17 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.91 | 0.167 | 2.61 | 0.135 | 0.104 | 1758 | 0.59 | 2214 | 146 | 28 | 2.49 |
| $Si_{500}$ | 1.89 | 0.186 | 2.60 | 0.143 | 0.109 | 1570 | 0.61 | 1891 | 136 | 29 | 2.63 |
| CD (0.05) | NS | 0.008 | NS | 0.005 | NS | 61 | NS | 180 | NS | NS | 0.12 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.90 | 0.178 | 2.55 | 0.135 | 0.108 | 1666 | 0.63 | 2115 | 137 | 29 | 2.45 |
| $K_{70}$ | 1.90 | 0.175 | 2.67 | 0.142 | 0.104 | 1662 | 0.58 | 1990 | 144 | 28 | 2.68 |
| CD (0.05) | NS | NS | 0.08 | 0.005 | NS | NS | NS | NS | NS | NS | 0.12 |

Among the sources, sodium silicate recorded the highest content of N and Na and lowest content of P, Ca, Fe and $SiO_2$. Contents of K, Mg, S, Mn and Zn did not vary among the sources.

Increasing the level of silica from 250 kg to 500 kg $ha^{-1}$ increased the contents of P, Ca and $SiO_2$ by 11.4, 5.9 and 5.6 per cent and decreased the contents of S and Fe by 10.7 and 14.6 per cent.

The levels of K had significant effect on the contents of K, Ca and $SiO_2$.

4.2.4.1 Residual effects of treatments on nutrient uptake at panicle initiation

*a. Without potash (Table 57)*

A perusal of the data showed that the general residual effect of the treatments significantly decreased the Mg, Na and Mn uptake by 21.1, 33.3 and 22.9 per cent and increased the uptake of $SiO_2$ by 32.7 per cent.

Sources of silica had significant residual effect on the uptake of N, P, K, Ca, Mg, S, Na, Fe, Mn and $SiO_2$. Among the three sources, fine silica recorded the highest uptake of all the nutrients except N, followed by rice husk and sodium silicate.

Application of 500 kg Si $ha^{-1}$ had significantly increased the Ca uptake but reduced the Fe uptake by 10.6 and 9.5 per cent respectively, over 250 kg Si $ha^{-1}$.

Increasing the level of K from 52.5 to 70 kg $ha^{-1}$ decreased the uptake of N, P, S, Fe and Zn by 3.5, 14, 12.2, 10.8 and 11.3 per cent respectively.

*b. With potash (Table 58)*

Data on nutrient uptake at panicle initiation showed that the general residual effect of the treatments was significant in respect of all the major nutrients and Fe and $SiO_2$.

Table 57. Residual effects of treatments on nutrient uptake (kg $ha^{-1}$) of rice at PI (without potash)

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 48.5 | 4.4 | 55.3 | 3.75 | 4.18 | 4.4 | 31.8 | 4.96 | 0.406 | 0.068 | 89.9 |
| Rest | 47.9 | 4.0 | 50.4 | 3.67 | 3.30 | 4.6 | 21.1 | 4.99 | 0.313 | 0.067 | 120.2 |
| CD (0.05) | NS | NS | NS | NS | 0.49 | NS | 4.0 | NS | 0.07 | NS | 18.4 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 54.7 | 3.3 | 45.1 | 3.11 | 2.95 | 4.4 | 20.3 | 4.53 | 0.285 | 0.062 | 110.7 |
| Fine silica | 42.6 | 4.8 | 56.3 | 4.41 | 3.84 | 5.0 | 23.2 | 5.38 | 0.351 | 0.072 | 134.1 |
| Rice husk | 46.3 | 3.9 | 49.9 | 3.50 | 3.12 | 4.4 | 19.9 | 5.07 | 0.303 | 0.066 | 115.7 |
| CD (0.05) | 4.6 | 0.7 | 7.6 | 0.39 | 0.33 | 0.5 | 3.1 | 0.59 | 0.05 | NS | 14.4 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 46.6 | 4.0 | 51.3 | 3.49 | 3.31 | 4.7 | 20.6 | 5.24 | 0.316 | 0.066 | 115.7 |
| $Si_{500}$ | 49.1 | 4.0 | 49.6 | 3.86 | 3.30 | 4.5 | 21.6 | 4.74 | 0.310 | 0.067 | 124.7 |
| CD (0.05) | NS | NS | NS | 0.32 | NS | NS | NS | 0.48 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 48.7 | 4.3 | 51.8 | 3.74 | 3.39 | 4.9 | 21.9 | 5.28 | 0.332 | 0.071 | 123.4 |
| $K_{70}$ | 47.0 | 3.7 | 49.1 | 3.60 | 3.21 | 4.3 | 20.4 | 4.71 | 0.294 | 0.063 | 117.0 |
| CD (0.05) | 0.5 | 0.5 | NS | NS | NS | 0.4 | NS | 0.48 | NS | 0.007 | NS |

**Table 58. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of rice at PI (with potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 47.8 | 3.8 | 50.3 | 3.64 | 1.81 | 3.6 | 20.9 | 4.02 | 0.475 | 0.075 | 63.3 |
| Rest | 58.0 | 5.3 | 79.8 | 4.23 | 3.22 | 5.1 | 18.0 | 6.26 | 0.427 | 0.087 | 78.7 |
| CD (0.05) | 5.9 | 0.7 | 7.9 | 0.43 | 0.37 | 0.4 | NS | 1.07 | NS | NS | 7.9 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 54.0 | 4.8 | 72.8 | 3.73 | 2.93 | 4.7 | 18.1 | 5.79 | 0.380 | 0.077 | 71.8 |
| Fine silica | 48.7 | 4.7 | 72.5 | 3.73 | 2.97 | 4.6 | 16.5 | 5.21 | 0.398 | 0.076 | 63.1 |
| Rice husk | 71.3 | 6.6 | 93.9 | 5.22 | 3.77 | 5.8 | 19.4 | 7.78 | 0.504 | 0.107 | 101.1 |
| CD (0.05) | 4.6 | 0.5 | 6.2 | 0.34 | 0.29 | 0.3 | 2.3 | 0.72 | 0.047 | 0.009 | 6.2 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 62.8 | 5.5 | 86.9 | 4.46 | 3.42 | 5.8 | 19.3 | 7.28 | 0.476 | 0.092 | 82.5 |
| $Si_{500}$ | 53.2 | 5.2 | 72.6 | 3.99 | 3.03 | 4.3 | 16.7 | 5.25 | 0.379 | 0.081 | 74.8 |
| CD (0.05) | 3.3 | 0.4 | 4.4 | 0.24 | 0.21 | 0.2 | 1.7 | 0.59 | 0.039 | 0.007 | 4.4 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 54.8 | 5.1 | 73.3 | 3.92 | 3.09 | 4.8 | 17.6 | 6.13 | 0.393 | 0.084 | 71.3 |
| $K_{70}$ | 61.2 | 5.6 | 86.3 | 4.53 | 3.36 | 5.3 | 18.4 | 6.40 | 0.462 | 0.090 | 86.0 |
| CD (0.05) | 3.3 | 0.4 | 4.4 | 0.24 | 0.21 | 0.2 | NS | NS | 0.039 | NS | 4.4 |

Sources of silica varied in their residual effect on nutrient uptake. Among the three sources rice husk recorded the highest uptake of all the nutrients followed by fine silica and sodium silicate.

Increasing the level of silica from 250 kg to 500 kg $ha^{-1}$ significantly reduced uptake of all the major and minor nutrients.

Increasing the level of K from 52.5 kg to 70 kg $ha^{-1}$ increased the uptake of N, P, K, Ca, Mg, S, Mn and $SiO_2$ significantly.

4.2.4.2 Two factor interaction effect on nutrient content at panicle initiation (Table 59 and 60)

*Interaction effect between sources and levels of silica*

*a. Without potash*

Interaction effect of sources and levels of silica significantly affected the nutrient content of the rice. Increasing the dose of silica as sodium silicate significantly increased the N, K and Ca content by 20.3, 27.4 and 29.2 per cent and reduced the Mn and $SiO_2$ content by 30.6 and 8.7 per cent over 250 kg level. Increasing the dose of silica as fine silica decreased the N, K and Zn content and increased the $SiO_2$ content by 6.7, 16.7, 10.7 and 39.2 per cent respectively. With respect to rice husk, the effect of varying doses was confined to the content of N and Ca only.

*b. With potash*

Residual effect of the applied sodium silicate at 500 kg Si $ha^{-1}$ increased the contents of N, P and Na by 10.1, 23.4 and 19.7 per cent and decreased the contents of K and Mn by 6.6 and 34.9 per cent as compared to the lower dose. With respect to fine silica, the effect was confined to N and Na content only. However increasing the level of silica as rice husk increased the P and $SiO_2$ content significantly.

**Table 59.Two factor interaction effects on nutrient content of rice at panicle initiation (without potash)**

| Treatments | N (%) | | K (%) | | Ca (%) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.72 | 2.07 | 1.64 | 2.09 | 0.120 | 0.155 | 152 | 106 | 27 | 29 | 5.19 | 4.74 |
| Fine silica | 2.10 | 1.96 | 2.28 | 1.90 | 0.164 | 0.160 | 121 | 138 | 28 | 25 | 4.16 | 5.79 |
| Rice husk | 1.89 | 2.03 | 2.09 | 2.11 | 0.137 | 0.159 | 120 | 133 | 26 | 29 | 4.98 | 4.72 |
| CD (0.05) | 0.11 | | 0.21 | | 0.008 | | 19 | | 3 | | 0.44 | |

| Treatments | Ca (%) | | S (ppm) | | Fe (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.137 | 0.138 | 1882 | 2100 | 1974 | 2131 | 28 | 27 |
| Fine silica | 0.165 | 0.159 | 1963 | 1724 | 2049 | 1924 | 26 | 29 |
| Rice husk | 0.133 | 0.162 | 1962 | 1763 | 2211 | 2045 | 24 | 28 |
| CD (0.05) | 0.008 | | 216 | | 166 | | 3 | |

| Treatments | Ca (%) | | S (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.144 | 0.137 | 1891 | 1988 | 29 | 25 | 4.89 | 4.66 |
| Si500 | 0.146 | 0.170 | 1982 | 1737 | 27 | 29 | 4.80 | 5.36 |
| CD (0.05) | 0.007 | | 176 | | 2.5 | | 0.36 | |

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

Residual effect of the combined application of sodium silicate with higher level of K increased the S content by 11.6 per cent. Higher level of K in combination with fine silica increased the Zn content and decreased the S content by 11.5 and 12.2 per cent with respect to rice husk the effect due to variation in K doses was confined to Ca, Fe and Zn content.

*b. With potash*

Data on two factor interaction showed that application of higher level of K in combination with fine silica increased the P and Mn content and decreased the N content by 12.5, 25.1 and 6.7 per cent respectively. In the case of sodium silicate, the interaction effect was confined to Ca whereas in the case of rice husk the effect was confined to the content of N.

*Interaction effect between levels of silica and K*

*a. Without potash*

At 250 kg $ha^{-1}$ Si, decreasing the K dose had decreased the Ca and Zn content by 4.9 and 13.8 per cent. At 500 kg Si $ha^{-1}$, the effect was significant on Ca, S and $SiO_2$ contents.

*b. With potash*

At 250 kg Si $ha^{-1}$, the effect of increasing levels of K was confined to N only. But at 500 kg level increasing the level of K increased the content of N and Ca and decreased the content of S and Fe by 5.4, 15.9, 5.5 and 15.5 per cent respectively.

**Table 60. Two factor interaction effects on nutrient content of rice at panicle initiation (with potash)**

| Treatments | N (%) | | P (%) | | K (%) | | Na (%) | | Mn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.89 | 2.08 | 0.158 | 0.195 | 2.74 | 2.56 | 0.61 | 0.73 | 166 | 108 | 2.68 | 2.61 |
| Fine silica | 1.85 | 1.63 | 0.165 | 0.170 | 2.55 | 2.60 | 0.64 | 0.54 | 137 | 149 | 2.22 | 2.27 |
| Rice husk | 1.98 | 1.96 | 0.178 | 0.193 | 2.55 | 2.65 | 0.53 | 0.56 | 134 | 153 | 2.59 | 3.03 |
| CD (0.05) | 0.10 | | 0.015 | | 0.13 | | 0.09 | | 23 | | 0.21 | |

| Treatments | N (%) | | P (%) | | Ca (%) | | Mn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 2.00 | 1.98 | 0.18 | 0.17 | 0.126 | 0.148 | 138 | 135 |
| Fine silica | 1.80 | 1.68 | 0.16 | 0.18 | 0.134 | 0.137 | 127 | 159 |
| Rice husk | 1.91 | 2.03 | 0.19 | 0.18 | 0.146 | 0.142 | 147 | 140 |
| CD (0.05) | 0.10 | | 0.015 | | 0.008 | | 23 | |

| Treatments | N (%) | | Ca (%) | | S (ppm) | | Fe (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 1.96 | 1.85 | 0.138 | 0.132 | 1717 | 1799 | 2185 | 2244 | 2.48 | 2.51 |
| Si500 | 1.84 | 1.94 | 0.132 | 0.153 | 1614 | 1525 | 2046 | 1736 | 2.43 | 2.84 |
| CD (0.05) | 0.08 | | 0.007 | | 87 | | 254 | | 0.17 | |

4.2.5 Residual effects of treatments on nutrient content at flowering

*a. Without potash (Table 61)*

A scrutiny of the data showed that the applied treatments in the preceeding season had significant residual effect only on $SiO_2$ in the succeeding season.

Among the three sources, sodium silicate increased the N, P, Mg and $SiO_2$ contents compared to fine silica by 8.1, 46.8, 10.1 and 3.0 per cent and reduced the Mn content by 13.1 per cent. As compared to rice husk, the increase of P and Mg was 31.9 and 5.7 per cent and decrease of Ca, Fe, Mn and Zn was 6.0, 10.2, 14.6 and 13.3 per cent respectively.

Application of the levels of silica had significant residual effect on N and Fe content whereas other nutrients were not affected. But increasing the levels of K decreased the Ca and Zn content by 5.0 and 12.5 per cent respectively.

*b. With potash (Table 62)*

The overall residual effects of the treatments showed superiority over control with respect to P, K, Ca, Mg and S contents but was inferior in the content of Na.

Residual effect of the various sources of silica reflected on P, Ca, Mg, S, Na and Fe contents at the flowering stage.

Increasing the levels of silica from 250 to 500 kg $ha^{-1}$ reduced the Ca and Fe content but increased the $SiO_2$ content by 11.9, 8.4 and 5.6 per cent respectively.

Levels of K had significant effect on Ca, S and Na contents only.

**Table 61. Residual effects of treatments on nutrient content of rice at flowering (without potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.91 | 0.068 | 1.30 | 0.171 | 0.178 | 1484 | 0.58 | 668 | 737 | 27.5 | 3.53 |
| Rest | 0.92 | 0.074 | 1.24 | 0.175 | 0.176 | 1348 | 0.62 | 676 | 757 | 29.9 | 6.15 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 0.16 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 0.94 | 0.091 | 1.21 | 0.171 | 0.185 | 1334 | 0.67 | 657 | 684 | 28.0 | 6.21 |
| Fine silica | 0.87 | 0.062 | 1.26 | 0.172 | 0.168 | 1358 | 0.58 | 640 | 787 | 29.5 | 6.03 |
| Rice husk | 0.95 | 0.069 | 1.26 | 0.182 | 0.175 | 1351 | 0.61 | 732 | 801 | 32.3 | 6.22 |
| CD (0.05) | 0.05 | 0.013 | NS | 0.009 | 0.007 | NS | NS | 33 | 34 | 2.1 | 0.12 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.90 | 0.078 | 1.25 | 0.177 | 0.177 | 1344 | 0.60 | 688 | 754 | 29.6 | 6.16 |
| $Si_{500}$ | 0.93 | 0.070 | 1.23 | 0.174 | 0.175 | 1351 | 0.63 | 664 | 761 | 30.3 | 6.14 |
| CD (0.05) | 0.03 | NS | NS | NS | NS | NS | NS | 24 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 0.91 | 0.075 | 1.23 | 0.180 | 0.175 | 1313 | 0.64 | 668 | 758 | 31.9 | 6.15 |
| $K_{70}$ | 0.93 | 0.073 | 1.25 | 0.171 | 0.176 | 1383 | 0.59 | 685 | 756 | 27.9 | 6.15 |
| CD (0.05) | NS | NS | NS | 0.007 | NS | NS | NS | NS | NS | 1.5 | NS |

**Table 62. Residual effects of treatments on nutrient content of rice at flowering (with potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.95 | 0.075 | 1.35 | 0.148 | 0.127 | 1085 | 0.550 | 718 | 694 | 32 | 3.12 |
| Rest | 0.91 | 0.096 | 1.69 | 0.215 | 0.147 | 1321 | 0.327 | 688 | 644 | 34 | 3.33 |
| CD (0.05) | NS | 0.011 | 0.12 | 0.007 | 0.012 | 125 | 0.099 | NS | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 0.94 | 0.104 | 1.67 | 0.192 | 0.142 | 1298 | 0.388 | 666 | 630 | 33 | 3.28 |
| Fine silica | 0.95 | 0.090 | 1.69 | 0.183 | 0.157 | 1467 | 0.288 | 725 | 636 | 34 | 3.28 |
| Rice husk | 0.87 | 0.098 | 1.70 | 0.194 | 0.141 | 1199 | 0.306 | 672 | 665 | 35 | 3.42 |
| CD (0.05) | NS | 0.008 | NS | 0.005 | 0.008 | 98 | 0.078 | 40 | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.89 | 0.096 | 1.70 | 0.202 | 0.145 | 1304 | 0.333 | 718 | 613 | 33 | 3.24 |
| $Si_{500}$ | 0.92 | 0.095 | 1.67 | 0.178 | 0.148 | 1338 | 0.321 | 658 | 674 | 34 | 3.42 |
| CD (0.05) | NS | NS | NS | 0.004 | NS | NS | NS | 28 | NS | NS | 0.13 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 0.89 | 0.098 | 1.64 | 0.186 | 0.149 | 1360 | 0.358 | 685 | 625 | 34 | 3.49 |
| $K_{70}$ | 0.91 | 0.093 | 1.73 | 0.194 | 0.144 | 1282 | 0.296 | 690 | 662 | 33 | 3.17 |
| CD (0.05) | NS | NS | 0.07 | 0.004 | NS | 69 | 0.055 | NS | NS | NS | 0.13 |

4.2.5.1 Residual effects of treatments on nutrient uptake at flowering

*4.2.5.2 a. Without potash (Table 63)*

A comparison of the general treatments effects with control showed that the applied treatment had residual effect only on $SiO_2$ uptake by increasing to 75.0 per cent.

A perusal of the data showed that the source varied in their effect on uptake of N, P, Mg, Fe and Mn.

Increasing the level of silica from 250 to 500 kg $ha^{-1}$ had no significant residual effect on the uptake of nutrients. But enhancement of level K had significant residual effect on S, Fe and Zn uptake.

*b. With potash (Table 64)*

Data on the nutrient uptake showed that the residual effect of the applied treatments in the previous season increased the P, K and Ca contents by 25.8, 21.8 and 24.6 per cent and reduced the Na uptake by 43.4 per cent.

Among the sources, sodium silicate recorded the lowest uptake of Mg, S and Fe and fine silica recorded the highest uptake.

Levels of silica had significant effect on Ca uptake only and other nutrients remained unaffected.

Enhancement in the level of K increased the K and Ca uptake by 10.4 and 9.4 per cent respectively.

4.2.5.2 Two factor interaction effect on nutrient content at flowering

*Interaction effect between sources and levels of silica (Table 65 and 66)*

*a. Without potash*

Data on interaction effect of sources and levels of silica showed that increasing the level of silica as sodium silicate increased the N and Zn content by

**Table 63. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of rice at flowering (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 76.6 | 5.8 | 109.4 | 14.5 | 15.0 | 12.5 | 49.5 | 5.6 | 6.2 | 0.23 | 296 |
| Rest | 77.2 | 6.3 | 104.3 | 14.8 | 14.8 | 11.4 | 52.0 | 5.7 | 6.4 | 0.25 | 518 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 57 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 81.3 | 7.8 | 104.6 | 14.9 | 16.1 | 11.6 | 58.0 | 5.7 | 5.9 | 0.24 | 539 |
| Fine silica | 68.8 | 5.0 | 99.9 | 13.7 | 13.3 | 10.8 | 45.4 | 5.1 | 6.3 | 0.24 | 479 |
| Rice husk | 81.5 | 5.9 | 108.4 | 15.8 | 15.1 | 11.7 | 52.6 | 6.4 | 6.9 | 0.28 | 537 |
| CD (0.05) | 8.4 | 1.4 | NS | NS | 1.7 | NS | NS | 0.5 | 0.7 | 0.02 | 45 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 76.3 | 6.6 | 105.9 | 15.0 | 15.0 | 11.4 | 51.1 | 5.9 | 6.4 | 0.25 | 523 |
| $Si_{500}$ | 78.1 | 6.0 | 102.7 | 14.6 | 14.7 | 11.3 | 52.9 | 5.6 | 6.3 | 0.25 | 513 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 74.0 | 6.2 | 100.1 | 14.7 | 14.4 | 10.7 | 52.3 | 5.5 | 6.2 | 0.26 | 504 |
| $K_{70}$ | 80.5 | 6.4 | 108.5 | 14.8 | 15.3 | 12.0 | 51.7 | 6.0 | 6.5 | 0.23 | 533 |
| CD (0.05) | 5.9 | NS | NS | NS | NS | 1.1 | NS | 0.4 | NS | 0.02 | NS |

Table 64. Residual effects of treatments on nutrient uptake (kg $ha^{-1}$) of rice at flowering (with potash)

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 85.2 | 6.6 | 121.8 | 13.4 | 11.5 | 9.8 | 50.0 | 6.5 | 6.3 | 0.29 | 281 |
| Rest | 79.1 | 8.3 | 148.3 | 16.7 | 12.9 | 11.6 | 28.3 | 6.1 | 5.7 | 0.30 | 291 |
| CD (0.05) | NS | 1.2 | 26.2 | 2.4 | NS | NS | 10.0 | NS | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 77.6 | 8.6 | 139.5 | 16.0 | 11.9 | 10.7 | 31.4 | 5.5 | 5.3 | 0.28 | 271 |
| Fine silica | 82.7 | 8.2 | 155.0 | 17.0 | 14.4 | 13.4 | 26.2 | 6.7 | 5.9 | 0.30 | 300 |
| Rice husk | 76.9 | 8.3 | 150.3 | 17.1 | 12.5 | 10.5 | 27.2 | 5.9 | 5.9 | 0.31 | 302 |
| CD (0.05) | NS | NS | NS | NS | 1.9 | 1.9 | NS | 0.8 | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 78.2 | 8.4 | 150.7 | 17.8 | 12.9 | 11.5 | 28.6 | 6.4 | 5.5 | 0.30 | 284 |
| $Si_{500}$ | 80.0 | 8.5 | 145.8 | 15.6 | 13.0 | 11.6 | 27.9 | 5.7 | 5.9 | 0.30 | 298 |
| CD (0.05) | NS | NS | NS | 1.3 | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 76.4 | 8.3 | 140.9 | 16.0 | 13.0 | 11.7 | 30.4 | 5.9 | 5.5 | 0.29 | 300 |
| $K_{70}$ | 81.8 | 8.3 | 155.6 | 17.5 | 12.9 | 11.4 | 26.2 | 6.2 | 5.9 | 0.30 | 282 |
| CD (0.05) | NS | NS | 14.2 | 1.3 | NS | NS | NS | NS | NS | NS | NS |

9.7 and 28.6 per cent and reduced the P, Ca, Mg and Fe by 18.0, 2.3, 5.8 and 23.6 per cent. In case of fine silica the effect was confined to Ca and Zn content only. However rice husk increased the Ca and Fe and reduced the $SiO_2$ content by 9.2, 20.2 and 3.5 per cent respectively.

*b. With potash*

Residual effect of sources and levels of silica was confined to P, Ca and Mn content at flowering. Ca alone was affected by the three sources of silica whereas rice husk alone affected the P, Ca and Mg content. The effect of fine silica was confined to Ca only.

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

Interaction effect between sources of silica and levels of K showed that application of sodium silicate with 70 kg K $ha^{-1}$ reduced the Fe, Mn and Zn content by 8.6, 11.8 and 19.4 per cent. But in the case of fine silica increasing dose of K increased the N, K, Fe and Mn content by 10.6, 12.7, 24.8 and 10.4 per cent. In the case of rice husk the effect was confined to S and Zn content only.

*b. With potash*

Residual interaction effect of sources of silica and levels of K showed that application of increased dose of K in combination with sodium silicate increased the Ca, N and Mn content by 7.0, 15.2 and 33.6 per cent, while fine silica reduced the Mg and Fe content by 12.6 and 7.0 per cent. The effect of rice husk was confined to Mg and Fe only.

*Interaction effect between levels of silica and K*

*a. Without potash*

Application of 70 kg K $ha^{-1}$ at 250 kg Si level decreased P content and increased the Fe content by 15.5 and 13.2 per cent. At 500 kg Si $ha^{-1}$ level higher

**Table 65.Two factor interaction effects on nutrient content of rice at flowering (without potash)**

| Treatments | N (%) | | P (%) | | Ca (%) | | Mg (%) | | Fe (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.893 | 0.980 | 0.100 | 0.082 | 0.178 | 0.165 | 0.191 | 0.180 | 745 | 569 | 24.5 | 31.5 | 6.12 | 6.29 |
| Fine silica | 0.842 | 0.893 | 0.068 | 0.057 | 0.179 | 0.166 | 0.168 | 0.167 | 655 | 624 | 32.5 | 26.5 | 6.05 | 6.00 |
| Rice husk | 0.964 | 0.928 | 0.065 | 0.073 | 0.174 | 0.190 | 0.171 | 0.179 | 665 | 799 | 31.8 | 32.8 | 6.35 | 6.13 |
| CD (0.05) | 0.06 | | 0.15 | | 0.011 | | 0.009 | | 41 | | 2.5 | | 0.15 | |

| Treatments | N (%) | | K (%) | | S (ppm) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.963 | 0.910 | 1.20 | 1.21 | 1346 | 1323 | 687 | 628 | 727 | 641 | 31 | 25 |
| Fine silica | 0.824 | 0.911 | 1.18 | 1.33 | 1347 | 1369 | 569 | 710 | 748 | 826 | 29 | 30 |
| Rice husk | 0.928 | 0.964 | 1.29 | 1.23 | 1246 | 1456 | 748 | 716 | 800 | 802 | 36 | 29 |
| CD (0.05) | 0.058 | | 0.11 | | 132 | | 41 | | 19 | | 2.5 | |

| Treatments | P (%) | | S (ppm) | | Fe (ppm) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.084 | 0.071 | 1360 | 1329 | 646 | 731 |
| Si500 | 0.066 | 0.075 | 1266 | 1437 | 690 | 638 |
| CD (0.05) | 0.011 | | 108 | | 33 | |

**Table 66. Two factor interaction effects on nutrient content of rice at flowering (with potash)**

| Treatments | P (%) | | Ca (%) | | Mn (ppm) | |
|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.110 | 0.098 | 0.209 | 0.176 | 571 | 688 |
| Fine silica | 0.090 | 0.090 | 0.199 | 0.168 | 670 | 603 |
| Rice husk | 0.088 | 0.098 | 0.199 | 0.190 | 599 | 731 |
| CD (0.05) | 0.01 | | 0.007 | | 107 | |

| Treatments | Ca (%) | | Mg (%) | | Fe (ppm) | | Mn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.186 | 0.199 | 0.132 | 0.152 | 668 | 665 | 539 | 720 |
| Fine silica | 0.182 | 0.185 | 0.167 | 0.146 | 752 | 699 | 638 | 635 |
| Rice husk | 0.192 | 0.197 | 0.149 | 0.133 | 637 | 707 | 699 | 631 |
| CD (0.05) | 0.007 | | 0.012 | | 49 | | 107 | |

| Treatments | S (ppm) | |
|---|---|---|
| | K52.5 | K70.0 |
| Si250 | 1449 | 1159 |
| Si500 | 1271 | 1406 |
| CD (0.05) | 98 | |

level of K increased S and reduced Fe constant by 11.9 and 7.5 per cent respectively.

*b. With potash*

Increasing the level of K at the two levels of silica had significant effect on S content only.

4.2.6 Residual effects of treatments on nutrient content of straw at harvest

*a. Without potash (Table 67)*

Compared to control the overall treatment effect had increased the contents of Ca and S by 9.6 and 13.7 per cent and reduced the Na and Zn content by 11.0, 11.1 per cent in the straw.

Comparison of residual effect of the sources of silica showed that application of sodium silicate reduced the K and Zn content by 16.7 and 8.5 per cent and increased the Ca, S, Na and Mn by 13.0, 13.6, 18.9 and 12.7 per cent, over fine silica.

Application of 500 kg Si $ha^{-1}$ decreased the K content and increased the S and Zn content by 4.0, 8.1 and 5.6 per cent respectively. In the case of levels of K, the effect was confined to K and Na only.

*b. With potash (Table 68)*

Compared to control, the general treatment effect increased the K and Ca content by 11.3 and 4.7 per cent and decreased the N, Na, Fe and Mn content by 11.4, 26.9, 19.6 and 14.2 per cent respectively.

Source of silica varied in their effect on N, K, Ca, Mg, S, Fe, Mn, Zn and $SiO_2$ contents of straw. Sodium silicate recorded the maximum content of N, Ca, Zn and $SiO_2$. K, S and Mg was maximum in rice husk. Fine silica recorded the maximum content of Fe and Mn.

**Table 67. Residual effects of treatments on nutrient content of rice of straw at harvest (without potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.74 | 0.090 | 2.23 | 0.270 | 0.211 | 1341 | 1.45 | 614 | 1109 | 63 | 20.53 |
| Rest | 0.73 | 0.104 | 2.18 | 0.296 | 0.211 | 1524 | 1.29 | 557 | 1110 | 56 | 20.58 |
| CD (0.05) | NS | NS | NS | 0.018 | NS | 125 | 0.01 | NS | NS | 4.1 | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 0.74 | 0.074 | 1.94 | 0.313 | 0.208 | 1609 | 1.45 | 562 | 1159 | 54 | 20.54 |
| Fine silica | 0.72 | 0.067 | 2.33 | 0.277 | 0.209 | 1417 | 1.22 | 542 | 1028 | 59 | 20.47 |
| Rice husk | 0.74 | 0.171 | 2.28 | 0.298 | 0.216 | 1546 | 1.21 | 567 | 1142 | 54 | 20.74 |
| CD (0.05) | NS | NS | 0.09 | 0.014 | 0.005 | 98 | 0.08 | 86 | 62 | 3.3 | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.73 | 0.136 | 2.23 | 0.295 | 0.210 | 1465 | 1.28 | 546 | 1106 | 54 | 20.73 |
| $Si_{500}$ | 0.73 | 0.073 | 2.14 | 0.297 | 0.212 | 1583 | 1.31 | 569 | 1113 | 57 | 20.44 |
| CD (0.05) | NS | NS | 0.06 | NS | NS | 70 | NS | NS | NS | 2.3 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 0.74 | 0.075 | 2.14 | 0.301 | 0.211 | 1499 | 1.33 | 565 | 1125 | 55 | 20.47 |
| $K_{70}$ | 0.72 | 0.133 | 2.23 | 0.291 | 0.212 | 1549 | 1.25 | 549 | 1094 | 57 | 20.70 |
| CD (0.05) | NS | NS | 0.06 | NS | NS | NS | 0.05 | NS | NS | NS | NS |

**Table 68. Residual effects of treatments on nutrient content of rice of straw at harvest (with potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.88 | 0.090 | 1.95 | 0.298 | 0.198 | 1348 | 0.78 | 967 | 1300 | 42.0 | 5.64 |
| Rest | 0.78 | 0.076 | 2.17 | 0.312 | 0.186 | 1400 | 0.57 | 1202 | 1116 | 43.1 | 6.02 |
| CD (0.05) | 0.06 | NS | 0.08 | 0.009 | NS | NS | 0.09 | 157 | 125 | NS | 0.38 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 0.88 | 0.073 | 2.20 | 0.319 | 0.185 | 1424 | 0.61 | 1133 | 1140 | 47.9 | 6.45 |
| Fine silica | 0.74 | 0.071 | 2.09 | 0.316 | 0.178 | 1315 | 0.54 | 1289 | 1165 | 41.8 | 5.65 |
| Rice husk | 0.73 | 0.084 | 2.21 | 0.302 | 0.195 | 1460 | 0.57 | 1185 | 1041 | 39.8 | 5.96 |
| CD (0.05) | 0.05 | NS | 0.06 | 0.007 | 0.009 | 112 | NS | 123 | 98 | 3.5 | 0.30 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 0.80 | 0.078 | 2.17 | 0.312 | 0.183 | 1366 | 0.56 | 1192 | 1091 | 41.8 | 5.88 |
| $Si_{500}$ | 0.77 | 0.073 | 2.17 | 0.310 | 0.189 | 1434 | 0.59 | 1212 | 1142 | 44.4 | 6.15 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | 2.5 | 0.21 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{32.5}$ | 0.78 | 0.078 | 2.10 | 0.318 | 0.188 | 1307 | 0.63 | 1265 | 1106 | 43.4 | 6.06 |
| $K_{70}$ | 0.79 | 0.074 | 2.24 | 0.306 | 0.183 | 1493 | 0.52 | 1139 | 1128 | 42.8 | 5.98 |
| CD (0.05) | NS | NS | 0.04 | 0.005 | NS | 79 | 0.05 | 87 | NS | NS | NS |

Levels of silica had significant effect on Zn and $SiO_2$ contents only. In the case of levels of K, the effect was significant on the content of K, Ca, S, Na and Fe.

4.2.6.1 Residual effects of treatments on nutrient uptake of straw

*a. Without potash (Table 69)*

The overall residual treatment effect was not significant on the uptake of any nutrients by straw.

Residual effect of sources of silica was confined to the uptake of Ca, Na and Fe.

Levels of silica had no residual effect on nutrient uptake. But the levels of K had increased the K uptake significantly.

*b. With potash (Table 70)*

Compared to control, the general residual effect of treatments significantly increased the N, P, Mg, Na and Mn uptake.

Sources of silica significantly affected the uptake of N, K, Ca, Mg, Fe, Mn, Zn and $SiO_2$. Sodium silicate recorded the lowest uptake of Mg, Fe and Mn and fine silica recorded the maximum.

Increasing the level of silica from 250 to 500 kg $ha^{-1}$ decreased the N, P, K, Ca,.Mg, Fe and $SiO_2$ contents by 13.5, 11.1, 9.2, 9.0, 4.7, 7.1 and 4.9 per cent respectively. Application of increased dose of 70 kg K $ha^{-1}$ had significant effect on K and Na only.

Table 69. **Residual effects of treatments on nutrient uptake (kg $ha^{-1}$) of straw at harvest (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 22.4 | 2.8 | 67.9 | 8.3 | 6.4 | 4.1 | 44 | 2.8 | 3.4 | 0.19 | 627 |
| Rest | 24.0 | 2.4 | 70.7 | 9.7 | 6.9 | 5.0 | 43 | 3.3 | 3.7 | 0.19 | 672 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 26.5 | 2.7 | 69.7 | 11.3 | 7.5 | 5.7 | 52 | 3.8 | 4.2 | 0.19 | 738 |
| Fine silica | 22.5 | 2.1 | 71.9 | 8.6 | 6.5 | 4.4 | 38 | 3.3 | 3.2 | 0.18 | 632 |
| Rice husk | 22.9 | 2.4 | 70.6 | 9.2 | 6.7 | 4.8 | 38 | 2.8 | 3.6 | 0.17 | 647 |
| CD (0.05) | NS | NS | NS | 1.8 | NS | NS | 10 | 0.7 | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 23.7 | 2.4 | 71.2 | 9.6 | 6.8 | 4.8 | 42 | 3.3 | 3.6 | 0.18 | 671 |
| $Si_{500}$ | 24.2 | 2.4 | 70.3 | 9.8 | 7.0 | 5.2 | 43 | 3.3 | 3.7 | 0.19 | 674 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 24.1 | 2.4 | 69.1 | 9.8 | 6.9 | 4.9 | 44 | 3.2 | 3.7 | 0.18 | 667 |
| $K_{70}$ | 23.8 | 2.3 | 72.3 | 9.6 | 6.9 | 5.1 | 42 | 3.4 | 3.6 | 0.19 | 678 |
| CD (0.05) | NS | NS | 13 | NS | NS | NS | NS | NS | NS | NS | NS |

**Table 70. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of straw at harvest (with potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 32.6 | 3.3 | 72.6 | 11.1 | 7.4 | 5.0 | 28.8 | 3.6 | 4.8 | 0.16 | 210 |
| Rest | 26.3 | 2.5 | 72.9 | 10.5 | 6.2 | 4.7 | 19.2 | 4.0 | 3.7 | 0.15 | 201 |
| CD (0.05) | 2.4 | 0.6 | NS | NS | 0.5 | NS | 2.7 | NS | 0.4 | NS | NS |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 28.5 | 2.4 | 72.4 | 10.4 | 6.0 | 4.6 | 19.6 | 3.6 | 3.7 | 0.16 | 209 |
| Fine silica | 27.3 | 2.6 | 76.0 | 11.5 | 6.5 | 4.8 | 19.9 | 4.7 | 4.2 | 0.15 | 205 |
| Rice husk | 23.2 | 2.6 | 70.5 | 9.6 | 6.2 | 4.6 | 18.0 | 3.7 | 3.3 | 0.13 | 189 |
| CD (0.05) | 1.7 | NS | 2.5 | 0.3 | 0.3 | NS | NS | 0.3 | 0.3 | 0.01 | 10 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 28.2 | 2.7 | 76.1 | 11.0 | 6.4 | 4.9 | 19.6 | 4.2 | 3.8 | 0.15 | 206 |
| $Si_{500}$ | 24.4 | 2.4 | 69.1 | 10.0 | 6.1 | 4.6 | 18.7 | 3.9 | 3.6 | 0.14 | 196 |
| CD (0.05) | 1.3 | 0.3 | 2.0 | 0.2 | 0.3 | NS | NS | 0.3 | NS | NS | 8 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 25.6 | 2.5 | 68.5 | 10.4 | 6.2 | 4.3 | 20.8 | 4.1 | 3.6 | 0.14 | 198 |
| $K_{70}$ | 26.9 | 2.5 | 77.4 | 10.5 | 6.3 | 5.1 | 17.5 | 3.9 | 3.8 | 0.15 | 203 |
| CD (0.05) | 1.3 | NS | NS | NS | NS | NS | 1.5 | NS | NS | NS | NS |

4.2.6.2 Two factor interaction effect on nutrient content of straw (Tables 71 and 72)

*Interaction effect between sources and levels of silica*

*a. Without potash*

Application of rice husk equivalent to 500 Kg Si $ha^{-1}$ decreased the K, Ca and Mn content by 13.9, 5.9 and 9.7 per cent over 250 kg Si $ha^{-1}$. However, fine silica increased the Ca, Mg and Mn contents by 8.7, 8.5 and 15.6 whereas sodium silicate decreased the Mg content by 4.2 per cent.

*b. With potash*

Application of sodium silicate at 500 kg $ha^{-1}$ increased the content of Fe and reduced the content of K by 25.8 and 8.7 per cent over the lower dose. In case of fine silica, the effect was confined to N and Mn only with respect to rice husk Fe and Mn content were reduced but K content was increased by 21.1, 10.9 and 6.5 per cent respectively.

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

The residual effect of sodium silicate with 70 kg Si $ha^{-1}$ increased the N, P and Fe by 10.0, 22.7 and 22.6 per cent and decreased, the Ca and Mg content by 5.3 and 6.9 per cent as compared to 52.5 kg K $ha^{-1}$. With respect to fine silica, N, P and Na content were decreased by 17.7, 13.3 ad 17.9 per cent and K and Mg were increased by 18.2 and 9.6 per cent with the increase in dose of K. The residual effect of rice husk in combination with K was continued to Ca content.

*b. With potash*

Combined effect of sources of Si and levels of K showed that application of sodium silicate in combination with 70 kg K $ha^{-1}$ increased the contents of Ca and S by 6.2 and 31.0 per cent over 52.5 kg K $ha^{-1}$. But fine silica when combined with increased K decreased the Ca and Fe content by 9.4 and 15.2

**Table 71. Two factor interaction effects on nutrient content of straw (without potash)**

| Treatments | K (%) | | Ca (%) | | Mg (%) | | Mn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 1.93 | 1.96 | 0.312 | 0.315 | 0.213 | 0.204 | 1163 | 1154 |
| Fine silica | 2.33 | 2.34 | 0.266 | 0.289 | 0.200 | 0.217 | 954 | 1103 |
| Rice husk | 2.45 | 2.11 | 0.307 | 0.289 | 0.217 | 0.215 | 1201 | 1084 |
| CD (0.05) | 0.11 | | 0.017 | | 0.006 | | 76 | |

| Treatments | Ca (%) | | Mg (%) | | Na (%) | | Fe (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.307 | 0.283 | 0.207 | 0.214 | 1.28 | 1.28 | 947 | 1069 |
| Si500 | 0.295 | 0.300 | 0.215 | 0.209 | 1.39 | 1.23 | 1010 | 986 |
| CD (0.05) | 0.014 | | 0.005 | | 0.08 | | 86 | |

| Treatments | N (%) | | P (%) | | K (%) | | Ca (%) | | Mg (%) | | Na (%) | | Fe (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.70 | 0.77 | 0.141 | 0.173 | 1.96 | 1.93 | 0.322 | 0.305 | 0.216 | 0.201 | 1.48 | 1.43 | 941 | 1154 |
| Fine silica | 0.79 | 0.65 | 0.150 | 0.130 | 2.14 | 2.53 | 0.270 | 0.284 | 0.199 | 0.218 | 1.34 | 1.10 | 1099 | 1002 |
| Rice husk | 0.72 | 0.75 | 0.131 | 0.132 | 2.31 | 2.25 | 0.311 | 0.284 | 0.217 | 0.215 | 1.19 | 1.23 | 896 | 925 |
| CD (0.05) | 0.07 | | 0.013 | | 0.11 | | 0.017 | | 0.006 | | 0.09 | | 106 | |

**Table 72.Two factor interaction effects on nutrient content of straw (with potash)**

| Treatments | N (%) | | K (%) | | Fe (ppm) | | Mn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.86 | 0.89 | 2.30 | 2.10 | 1003 | 1262 | 1084 | 1196 |
| Fine silica | 0.79 | 0.70 | 2.06 | 2.13 | 1249 | 1329 | 1084 | 1247 |
| Rice husk | 0.75 | 0.72 | 2.14 | 2.28 | 1325 | 1046 | 1106 | 985 |
| CD (0.05) | 0.06 | | 0.08 | | 151 | | 120 | |

| Treatments | Ca (%) | | S (ppm) | | Fe (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.309 | 0.328 | 1233 | 1615 | 1102 | 1163 | 47 | 49 |
| Fine silica | 0.331 | 0.300 | 1306 | 1324 | 1395 | 1183 | 42 | 42 |
| Rice husk | 0.315 | 0.289 | 1382 | 1539 | 1299 | 1072 | 42 | 37 |
| CD (0.05) | 0.008 | | 137 | | 151 | | 4.3 | |

| Treatments | Na (%) | | $SiO_2$ (%) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.65 | 0.48 | 6.03 | 5.73 |
| Si500 | 0.62 | 0.56 | 6.08 | 6.23 |
| CD (0.05) | 0.07 | | 0.30 | |

per cent. Increasing the dose of K decreased the Ca, S, Fe and Zn by 8.3, 10.2, 17.5 and 11.9 per cent in the case of rice husk.

*Interaction between levels of silica and K*

*a. Without potash*

Application of 70 kg K $ha^{-1}$ at 250 kg Si $ha^{-1}$ increased the Mg and Fe contributing 3.4 and 12.9 per cent and decreased the Ca content by 7.8 per cent and 52.5 kg K $ha^{-1}$. At 500 kg Si $ha^{-1}$ the effect of various levels of K was confined to contents of Mg, Na and Fe.

*b. With potash*

The interaction effect of levels of silica with levels of K had significant effect on the contents of Na and $SiO_2$.

4.2.7 Residual effects of treatments on nutrient content of grain at harvest

*a. Without potash (Table 73)*

Compared to control, the residual effect of the overall treatments significantly increased the contents K N, P, Ca, Mg, Fe, Mn and $SiO_2$.

Sources of silica had significant residual effect on the content of P, S, Fe, Zn and $SiO_2$ and the contents were maximum in sodium silicate.

Application of higher level of silica increased the Fe content by 5.3 per cent. The levels of K had no significant residual effect on nutrient content of grain.

*b. With potash (Table 74)*

The general residual effect of the treatments recorded higher content of N, P, K, Ca, Fe, Zn and $SiO_2$ in grain than control.

Among the sources, sodium silicate recorded the maximum contents of P, K, Ca, Mg, S and Mn followed by rice husk and fine silica. In the case of N, fine silica recorded higher content followed by sodium silicate and rice husk.

**Table 73. Residual effects of treatments on nutrient content of rice of grain at harvest (without potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 1.26 | 0.113 | 0.55 | 0.029 | 0.105 | 1375 | 0.05 | 614 | 602 | 19.5 | 3.26 |
| Rest | 1.28 | 0.129 | 0.56 | 0.031 | 0.113 | 1314 | 0.05 | 557 | 558 | 17.8 | 4.93 |
| CD (0.05) | NS | 0.011 | NS | NS | 0.006 | NS | NS | NS | NS | NS | 0.49 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 1.27 | 0.138 | 0.54 | 0.029 | 0.115 | 1506 | 0.05 | 562 | 556 | 15.0 | 4.54 |
| Fine silica | 1.31 | 0.122 | 0.57 | 0.032 | 0.112 | 1390 | 0.05 | 542 | 554 | 16.5 | 3.74 |
| Rice husk | 1.27 | 0.126 | 0.58 | 0.031 | 0.112 | 1045 | 0.05 | 567 | 560 | 21.8 | 4.68 |
| CD (0.05) | NS | 0.008 | NS | 0.003 | NS | 113 | NS | NS | NS | 2.5 | 0.38 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.32 | 0.132 | 0.57 | 0.030 | 0.110 | 1329 | 0.05 | 546 | 543 | 18.3 | 4.19 |
| $Si_{500}$ | 1.25 | 0.125 | 0.56 | 0.031 | 0.116 | 1298 | 0.05 | 569 | 573 | 17.3 | 4.44 |
| CD (0.05) | 0.07 | 0.006 | NS | NS | 0.004 | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.28 | 0.130 | 0.55 | 0.030 | 0.113 | 1356 | 0.05 | 565 | 561 | 17.7 | 4.28 |
| $K_{70}$ | 1.28 | 0.127 | 0.57 | 0.031 | 0.113 | 1271 | 0.05 | 549 | 557 | 18.4 | 4.36 |
| CD (0.05) | NS | NS | NS | NS | NS | 80 | NS | NS | NS | NS | NS |

**Table 74. Residual effects of treatments on nutrient content of rice of grain at harvest (with potash)**

| Treatments | N (%) | P (%) | K (%) | Ca (%) | Mg (%) | S (ppm) | Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | $SiO_2$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 1.26 | 0.110 | 0.60 | 0.032 | 0.110 | 1243 | 0.100 | 493 | 81 | 21.0 | 16.13 |
| Rest | 1.29 | 0.141 | 0.68 | 0.033 | 0.108 | 1218 | 0.090 | 508 | 69 | 22.0 | 20.22 |
| CD (0.05) | NS | 0.013 | 0.06 | NS | NS | NS | NS | NS | NS | NS | 1.12 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 1.23 | 0.154 | 0.71 | 0.033 | 0.109 | 1299 | 0.094 | 471 | 75 | 21.3 | 19.75 |
| Fine silica | 1.37 | 0.128 | 0.65 | 0.032 | 0.107 | 1192 | 0.088 | 537 | 68 | 22.4 | 20.14 |
| Rice husk | 1.26 | 0.154 | 0.68 | 0.033 | 0.109 | 1163 | 0.088 | 515 | 64 | 22.6 | 20.77 |
| CD (0.05) | 0.09 | 0.010 | 0.05 | NS | NS | 80 | NS | NS | NS | NS | 0.88 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 1.29 | 0.138 | 0.68 | 0.032 | 0.108 | 1164 | 0.088 | 540 | 73 | 21.0 | 20.19 |
| $Si_{500}$ | 1.28 | 0.139 | 0.68 | 0.033 | 0.108 | 1272 | 0.092 | 475 | 65 | 23.0 | 20.25 |
| CD (0.05) | NS | NS | NS | NS | NS | 56 | NS | 47 | NS | 1.2 | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 1.31 | 0.142 | 0.64 | 0.032 | 0.107 | 1250 | 0.096 | 519 | 71 | 22.1 | 20.29 |
| $K_{70}$ | 1.27 | 0.135 | 0.72 | 0.033 | 0.108 | 1187 | 0.083 | 496 | 67 | 21.9 | 20.15 |
| CD (0.05) | NS | NS | 0.04 | NS | NS | 56 | NS | NS | NS | NS | NS |

Between the two levels of silica, application of higher level of silica reduced the contents of N, P, Mg, Fe, Mn and $SiO_2$ by 7.4, 4.4, 5.7, 18.3 16.7 and 6.1 per cent respectively.

With respect to levels of K, the effect on nutrient content was not significant.

4.2.7.1 Residual effects of treatments on nutrient uptake of grain at harvest

*a. Without potash (Table 75)*

The general residual effect of treatments significantly increased the contents of N, P, Ca, Mg and $SiO_2$ over control.

Sources varied in their residual effects on contents of P, S, Zn and $SiO_2$ only.

Application of higher levels of silica and K had no residual effect on the nutrient uptake of grain.

*b. With potash (Table 76)*

Compared to control the overall residual effect of the treatments increased the N, P, K, Ca and $SiO_2$ by 15.4, 41.9, 28.1, 15.2 and 25.4 per cent, respectively.

The effect of sources of silica was confined to contents of N, P, K, Ca, Mg, S and $SiO_2$ only.

Higher levels of silica and K had no significant effect on the uptake of nutrients.

**Table 75. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of grain at harvest (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 33.8 | 3.1 | 14.8 | 0.78 | 2.8 | 3.7 | 1.3 | 1.6 | 1.6 | 0.052 | 87 |
| Rest | 41.6 | 4.2 | 18.3 | 0.99 | 3.7 | 4.3 | 1.6 | 1.8 | 1.8 | 0.058 | 141 |
| CD (0.05) | 5.5 | 0.7 | NS | 0.18 | 0.7 | NS | NS | 0.2 | 0.2 | NS | 30 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 42.6 | 4.7 | 18.3 | 0.97 | 3.9 | 5.1 | 1.7 | 1.9 | 1.9 | 0.051 | 153 |
| Fine silica | 40.7 | 3.8 | 17.8 | 0.99 | 3.5 | 4.4 | 1.6 | 1.7 | 1.7 | 0.052 | 117 |
| Rice husk | 41.6 | 4.1 | 18.8 | 1.00 | 3.7 | 3.4 | 1.6 | 1.9 | 1.9 | 0.071 | 154 |
| CD (0.05) | NS | 0.4 | NS | NS | NS | 0.6 | NS | 0.1 | NS | 0.010 | 20 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 42.4 | 4.2 | 18.2 | 0.97 | 3.5 | 4.3 | 1.6 | 1.8 | 1.8 | 0.059 | 135 |
| $Si_{500}$ | 40.9 | 4.1 | 18.4 | 1.00 | 3.8 | 4.3 | 1.7 | 1.9 | 1.9 | 0.057 | 147 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | 0.1 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 41.1 | 4.2 | 17.8 | 0.97 | 3.6 | 4.4 | 1.6 | 1.8 | 1.8 | 0.054 | 137 |
| $K_{70}$ | 42.2 | 4.2 | 18.8 | 1.00 | 3.7 | 4.2 | 1.7 | 1.8 | 1.8 | 0.061 | 145 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**Table 76. Residual effects of treatments on nutrient uptake (kg ha$^{-1}$) of grain at harvest (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 35.1 | 3.1 | 16.7 | 0.89 | 3.1 | 3.5 | 2.79 | 1.37 | 0.23 | 0.059 | 450 |
| Rest | 40.5 | 4.4 | 21.4 | 1.03 | 3.4 | 3.8 | 2.81 | 1.58 | 0.22 | 0.069 | 637 |
| CD (0.05) | 5.0 | 0.3 | 2.5 | 0.11 | NS | NS | NS | 0.21 | NS | 0.007 | 63 |
| *Forms of silica* | | | | | | | | | | | |
| Sodium silicate | 40.7 | 5.1 | 23.3 | 1.10 | 3.6 | 4.3 | 3.09 | 1.55 | 0.25 | 0.069 | 653 |
| Fine silica | 42.6 | 4.0 | 20.2 | 0.97 | 3.3 | 3.7 | 2.72 | 1.66 | 0.21 | 0.068 | 630 |
| Rice husk | 38.1 | 4.1 | 20.6 | 1.00 | 3.3 | 3.5 | 2.63 | 1.55 | 0.19 | 0.070 | 628 |
| CD (0.05) | 3.4 | 0.2 | 1.7 | 0.08 | 0.2 | 0.3 | NS | NS | 0.03 | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 42.0 | 4.5 | 22.0 | 1.05 | 3.5 | 3.8 | 2.83 | 1.75 | 0.24 | 0.068 | 657 |
| $Si_{500}$ | 38.9 | 4.3 | 20.8 | 1.00 | 3.3 | 3.9 | 2.79 | 1.43 | 0.20 | 0.070 | 617 |
| CD (0.05) | 2.8 | 0.2 | NS | NS | 0.2 | NS | NS | 0.11 | 0.02 | NS | 35 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 40.8 | 4.6 | 20.0 | 1.00 | 3.4 | 3.9 | 2.97 | 1.50 | 0.22 | 0.069 | 635 |
| $K_{70}$ | 40.1 | 4.3 | 22.8 | 1.05 | 3.4 | 3.8 | 2.65 | 1.61 | 0.21 | 0.069 | 640 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

### 4.2.7.2 Two factor interaction effects on nutrient content of grain (Tables 77 and 78)

*Interaction effect between sources and levels of silica*

*a. Without potash*

Application of increased dose of 500 kg Si $ha^{-1}$ as sodium silicate reduced the content of K and increased the content of Ca by 15.3 and 14.8 per cent. The effect of other sources was confined to Zn content.

*b. With potash*

Combined effect of sources and levels of silica showed that application of sodium silicate at 500 kg Si $ha^{-1}$ decreased the K, Fe and Mn contents by 14.5, 30.5 and 32.2 per cent. But the Zn content only showed an increase in the case of fine silica. With respect to rice husk, the effect was confined to K and Fe contents only.

*Interaction effect between sources of silica and levels of K*

*a. Without potash*

Data on residual effect of the two factor interaction among sources of silica and levels of K had showed significant variation in contents of P and S only. Increasing levels of K in combination with fine silica decreased the S content by 10.6 per cent. With respect to rice husk, P and S content decreased by 24.8 and 8.2 per cent.

*b. With potash*

Application of sodium silicate with in combination with levels of K had no significant effect on nutrient contents of grain, but the effect was evident on the content of S in the case of fine silica. Rice husk at higher dose of K reduced the P and S contents by 24.8 and 8.2 per cent.

**Table 77. Two factor interaction effects on nutrient content of grain (without potash)**

| Treatments | K (%) | | Ca (%) | | Zn (ppm) | |
|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.59 | 0.50 | 0.027 | 0.031 | 16 | 14 |
| Fine silica | 0.55 | 0.59 | 0.033 | 0.031 | 18 | 15 |
| Rice husk | 0.56 | 0.59 | 0.031 | 0.030 | 21 | 17 |
| CD (0.05) | 0.05 | | 0.003 | | 3 | |

| Treatments | P (%) | | Zn (ppm) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.139 | 0.138 | 13 | 17 |
| Fine silica | 0.115 | 0.128 | 16 | 17 |
| Rice husk | 0.137 | 0.116 | 22 | 21 |
| CD (0.05) | 0.010 | | 3 | |

| Treatments | K (%) | |
|---|---|---|
| | K52.5 | K70.0 |
| Si250 | 0.542 | 0.592 |
| Si500 | 0.567 | 0.550 |
| CD (0.05) | 0.044 | |

**Table 78.Two factor interaction effects on nutrient content of grain (with potash)**

| Treatments | K (%) | | Fe (ppm) | | Mn (ppm) | | Zn (ppm) | | $SiO_2$ (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 | Si250 | Si500 |
| Sodium silicate | 0.76 | 0.65 | 555 | 386 | 90 | 61 | 21 | 22 | 19.3 | 20.3 |
| Fine silica | 0.63 | 0.68 | 497 | 577 | 63 | 74 | 20 | 25 | 20.6 | 19.7 |
| Rice husk | 0.64 | 0.73 | 568 | 463 | 66 | 62 | 22 | 23 | 20.7 | 20.8 |
| CD (0.05) | 0.06 | | 82 | | 14 | | 2 | | 1.1 | |

| Treatments | P (%) | | S (ppm) | |
|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 |
| Sodium silicate | 0.150 | 0.158 | 1278 | 1321 |
| Fine silica | 0.123 | 0.133 | 1259 | 1126 |
| Rice husk | 0.153 | 0.115 | 1213 | 1112 |
| CD (0.05) | 0.012 | | 98 | |

| Treatments | P (%) | | S (ppm) | | Fe (ppm) | |
|---|---|---|---|---|---|---|
| | K52.5 | K70.0 | K52.5 | K70.0 | K52.5 | K70.0 |
| Si250 | 0.145 | 0.130 | 1096 | 1232 | 508 | 572 |
| Si500 | 0.138 | 0.140 | 1404 | 1141 | 531 | 420 |
| CD (0.05) | 0.010 | | 80 | | 67 | |

*Interaction effect between levels of silica and K*

*a. Without potash*

Combined effect of levels of silica and K was confined to 250 kg Si $ha^{-1}$ by increasing the S content by 9.2 per cent at higher level of K.

*b. With potash*

Interaction effect between levels of silica and K showed that increasing levels of K at 250 kg Si decreased the content of P by 10.3 per cent and increased the content of S by 12.4 per cent. At 500 kg Si $ha^{-1}$ application of S 70 kg K $ha^{-1}$ decreased the S and Fe contents by 18.7 and 20.9 per cent.

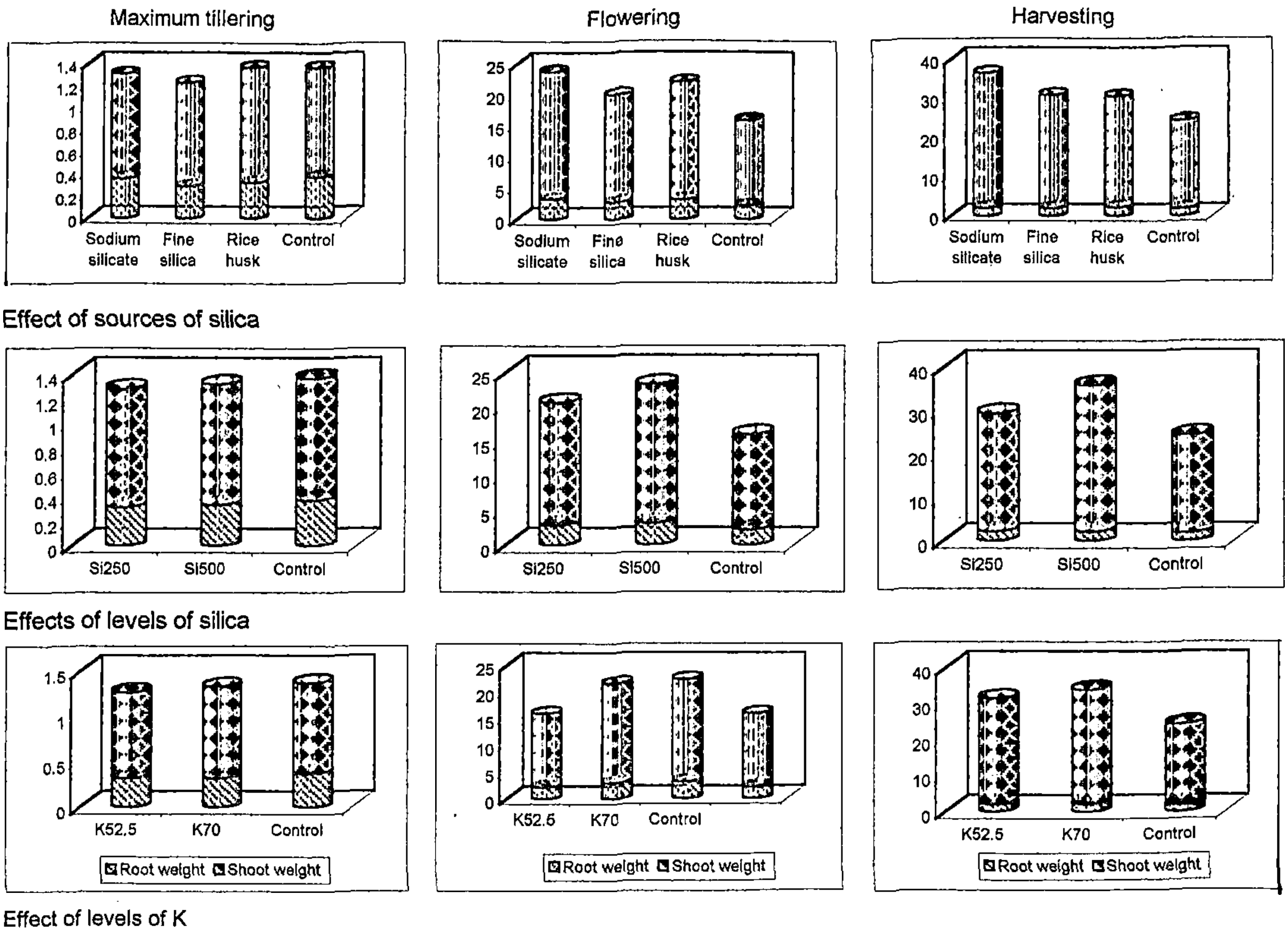
# DISCUSSION

# 5. DISCUSSION

The study entitled "Efficacy of silicon and potassium in the amelioration of iron in rice culture" was carried out during 1999-2000 at Agricultural Research Station, Mannuthy. The study was aimed to evaluate efficacy of silicon and potassium in ameliorating the stress influences of excess iron on rice productivity in laterite soils as well as to characterise their influences on growth and yield of rice. The results have been discussed in this context.

Results presented in Table 10 have shown that the over all treatment effect consisting of inclusion of silica and increasing the level K in the recommended practice have increased the yield of rice by 1000 kg $ha^{-1}$. Positive and significant influence of inclusion of silica and enhancing the level of K have been reported in laterite soils by Bridgit (1999). A closer scrutiny of the results will show that post panicle initiation increase in shoot weight and increased 1000 grain weight had been the contributing components to increased yield of grain and that the treatments did not generally exert any effect on the crop in its early stages of growth. These results would suggest that physiologically the treatments have facilitated a higher photosynthetic rate after panicle initiation, and its retention as a remoblisable fraction in the shoot, which was subsequently translocated in to the grain. Absence of any conspicuous increase in dry matter yield (Fig.3) before panicle initiation would justify the conclusion. Silica is considered as a beneficial element and potassium is known not to involve in the structural or metabolic processes of the plant. As such both of them are only facilitators. More over the yield increase of 1000 kg grain $ha^{-1}$ has been realised at the same level of N and P which implied that the treatment has increased the yield nutritionally by increasing the efficiency of dose of N and P in the physiological processes of synthesis and translocation in the plant system. Conversely, the low yield in the usual system of crop production in it would mean, is handicapped by some restrictive influences in the metabolic processes leading to low yield which is rectified by the treatment.

**Fig. 3. Effects of treatments on dry matter production (g/plant)**



The generalised treatment effect is the net effect of additional K which was soluble and three sources of silica viz., insoluble fine silica, degradable rice husk and gel like sodium silicate. It is also to be remembered that these two constitute the two most dominant minerals of the soil. A substantially significant effect by them by the very nature of response suggest the possibility of the restrictive influence being soil borne and translocated to the plant. Similar results have also been reported by Potty *et al.* (1992) and Bridgit (1999).

Generalised effect of treatment on foliar concentration of element (Tables 13 to 30) has brought out that shifting influence of the treatments had been to reduce Ca, Fe and Mn concentration in the foliage from the beginning, but without any internal improvement in conventionally applied N, P and K. However absorption of silica had increased. The trend can be seen to reflect in the uptake of the other elements also. Thus the mechanics of the components of treatments would appear to be restricting the foliar contents through their reduced uptake. The reduced uptake of Ca, Fe and Mn may be through cationic competition as is envisaged in the ratio low (Schofield, 1957 and Tinker, 1964). These results however strengthen the contention that the restrictive influences are soil borne and acting through the plant.

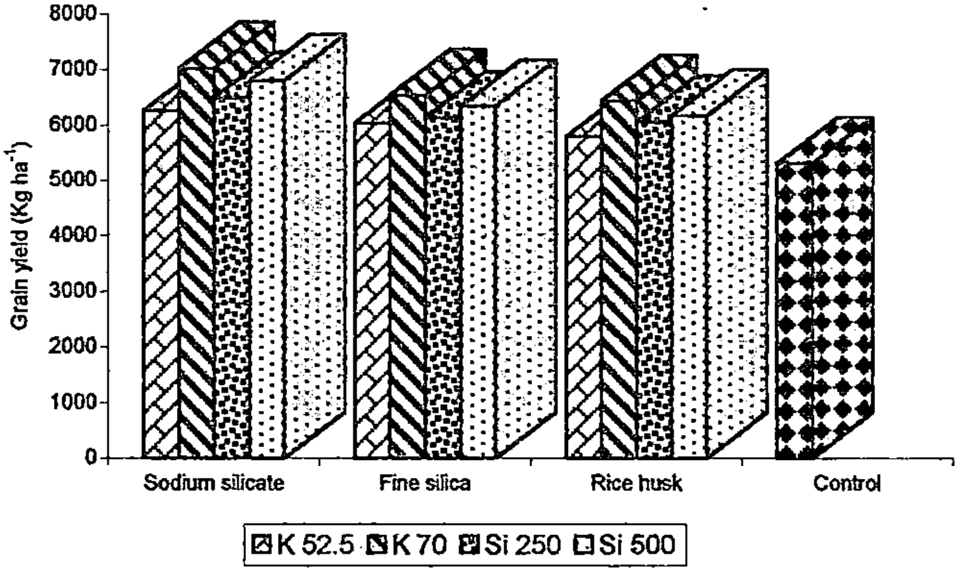
Foliar concentration regulates the rate of growth whereas uptake is the product of growth. Lower uptake values were associated with reduced foliar concentration in the early stages. However uptake had exceeded treatment effect which had evidently been due to increased dry matter production.

**Influence of treatment components**

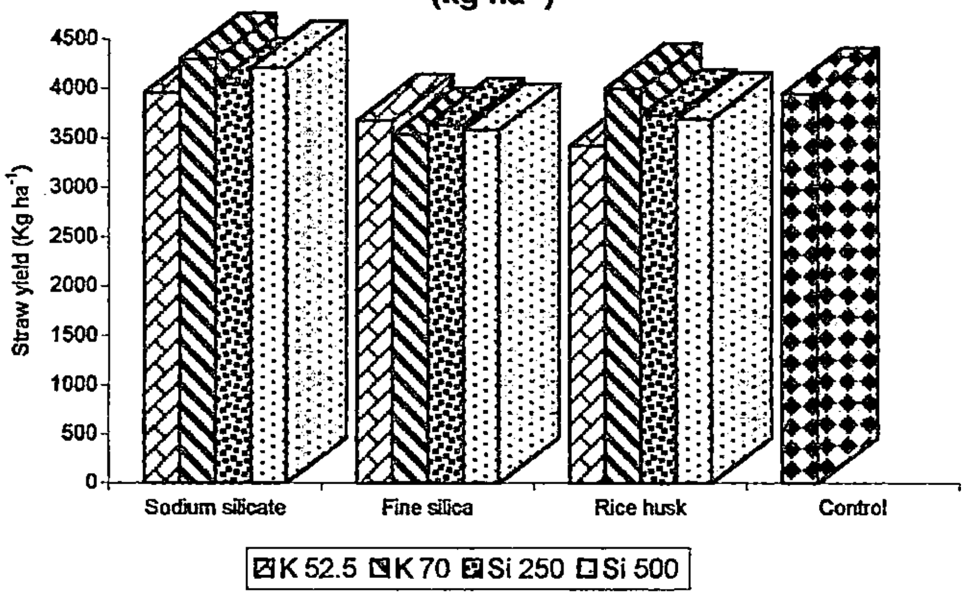
*A. Potassium*

A perusal of the data on the effect of K levels on growth and yield (Table 6, 7 and 10) will show that effects were identical with that of the generalised treatment effect but for the fact that the differences between highest level of 70 kg and medium level of 52.5 kg $ha^{-1}$ failed to reach the significance

## Fig. 4a. Effects of treatments on grain yield (kg ha$^{-1}$)




## Fig. 4b. Effects of treatments on Straw yield (kg ha$^{-1}$)



level, in growth attributes. However shoot, panicle and grain weight at harvesting stage was significantly improved. This effect may be because of the fact that due to solubility of the source of K, higher level might have increased the uptake resulting in higher shoot weight.

Nutritionally however effect of raising the level of K to 70 kg ha$^{-1}$ did not identically follow the line of generalised effects. Raising the level of K beyond 52.5 Kg ha$^{-1}$ failed to affect P, Ca and Mg contents but helped in steadily reducing the Fe and silica contents. Effect of reducing Fe alone was consistent throughout. This actually confirms that failure to increase the yield is due to the excess of Fe.

The data show that in deviation from the generalised effects higher level of K increased the uptake of N, P and K significantly at maximum tillering and did not affect Ca, Mg, Fe and Mn. But subsequently the effects of differences waned out which implied that higher levels beyond 52.5 kg ha$^{-1}$ may not have much effect.

*B. Effect of sources of Silica*

Variability in source effect of silica was manifested in almost all attributes studied unlike the level effect of K which tended to wane out beyond 52.5 kg ha$^{-1}$. Sodium silicate which recorded an yield of 6644 kg ha$^{-1}$ had been superior in all growth characteristics except root weight at panicle initiation, flowering and harvesting stages, in which rice husk manifested an advantage. Variability in source effect seems to be due to the variation in the reactivity of the source consequent of solubility and the degradability to manifest their specific effects.

Sources of silica significantly differed in their effect on yield (Fig.4a and 4b) and also the mechanics of growth and yield formation.

Effect of sodium silicate on rate of growth was slow in the beginning but surpassed other sources subsequently especially from flowering whereas the reverse was the case with the other sources. Application of sodium silicate increased the floret number as well as grain weight over other sources which implied that its positive effects had started well before panicle initiation stage. Mureta (1969) have reported that floret number is decided by the nutritional status of the plant one month before. Significantly higher straw yield in sodium silicate over others had been another sign of superiority of sodium silicate. An yield reduction of 531 kg $ha^{-1}$ in rice husk inspite of nearly identical 1000 grain weight would mean that the improvement in the role of rice husk might have been due to more efficient translocation only.

A scrutiny of the data in Tables 10, 13 and 17 showed that mode of action of the sources were more or less same. Only the efficiency varied which again would appear to be a function of reactivity consequent of solubility, degradability and resistance. Higher plant content of silica in sodium silicate applied plots at maximum tillering and panicle initiation and the highest grain weight in them appeared to be related. It is possible that percentage content of plant silica is an index of translocation efficiency.

Sodium silicate applied plots had also registered lowest content of Ca, Mg, and Mn at maximum tillering and Ca, Mg, Fe and Mn at panicle initiation. The fact that this was not related to $SiO_2$ content of the plant would suggest that role of silicates in reducing the plant content of these elements, though their influence is in rhizosphere and the variation in source effects is due to variation in rhizosphere influence. Tisdale *et al* (1993) have reported that in highly weathered soils iron will be present in three forms as discrete crystals, hydrouoxides of Fe and as coating over other particles. It is possible that Sodium silicate may form a coating over these and reduce the Fe release. Effect of fine silica may be by opening up the soil whereas degradable rice husk may initially act as fine silica and subsequently similar to sodium silicate.

Data presented in tables on source-level interaction of silica on content and uptake showed that soluble sodium silicate and insoluble fine silica and rice husk behaved differently. Insoluble sources tended to increase the content and uptake of all elements while soluble sodium silicate tended to reduce Ca, Fe and Mn contents as well as the uptake of almost all elements.

These elements are only marginally required in growth process. The higher uptake, probably a purely rhizophere effect, would only remain in the straw and the higher straw yield and narrower grain:straw ratio under fine silica and rice husk appeared to be means of accommodating these elements. Thus yield function under sodium silicate would appear to be through a restrictive influence of native elements increasing the metabolic efficiency of the plant whereas that of insoluble source would be to increase the over all contents.

**Source and level of silica and K interaction**

Behavioural pattern of the three factor interaction of sources and levels of silica and levels of K in relation to productivity had been best indicative of the functional nature of these components to translocation. The results indicated that content of unfavorable elements at flowering has nothing to do with translocation as the seed weight under sodium silicate and rice husk had been identical.

Comparative evaluation of the uptake figures are useful in realising the net effect of the treatments on yield formation and physiological efficiency of the inputs. The data presented in Tables 13 to 30 showed that yield improvement had not been due to a reduction of N, Mg, S and Zn. Among these only N had been the applied element. As such results would indicate that influences of excess contents of native elements are restricting the use efficiency of N. These results would imply that low productivity of rice in laterite soils of Kerala is not due to any inadequacy of any applied inputs but due to the over riding influence of native elements. As withdrawals are not possible, ameliorative management will only be the way out for increasing the yield.

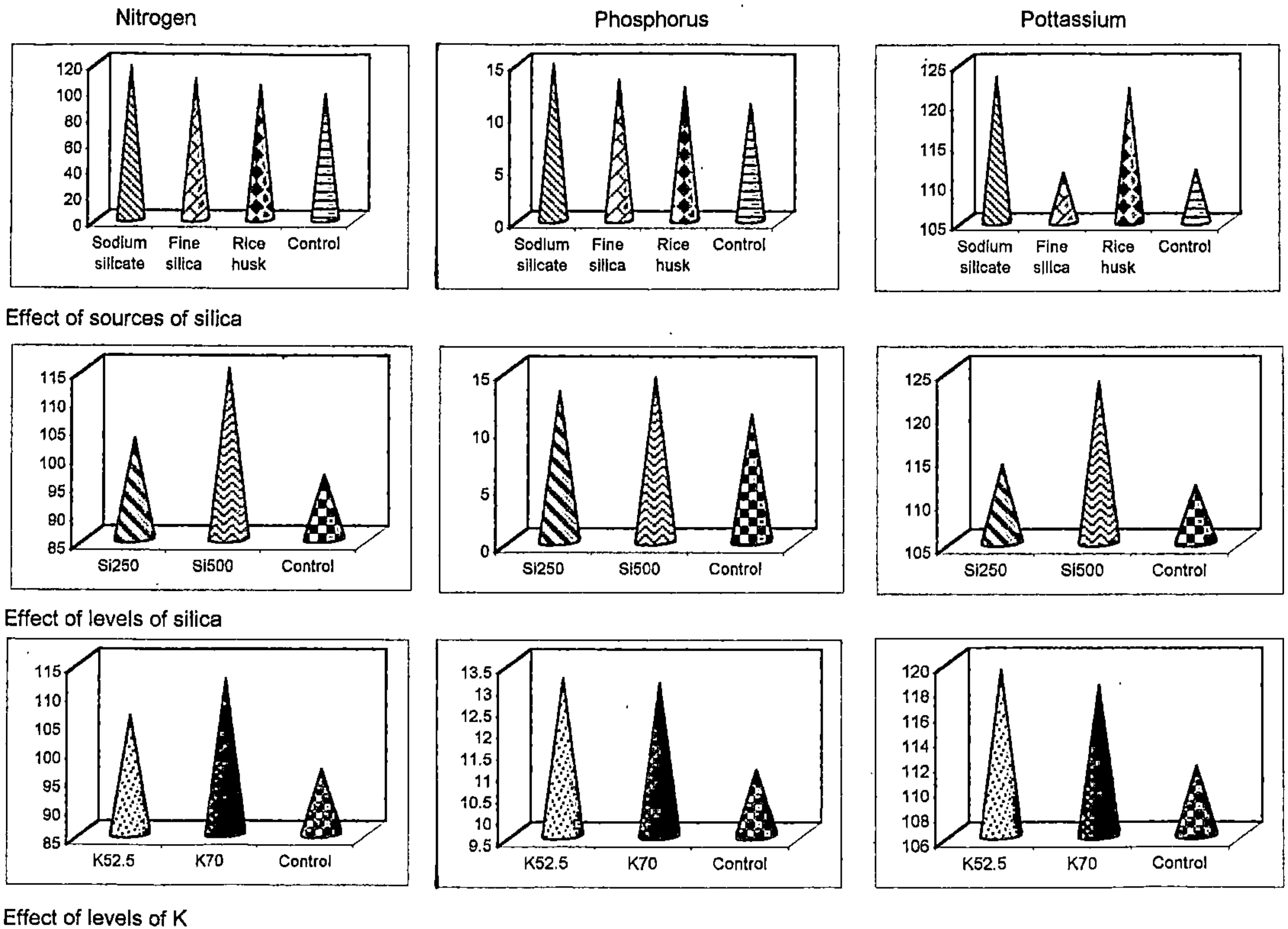
Existence of strong interaction among elements at all stages of growth as well as in grain and straw affects the content and uptake of other elements. Resultant yields due to treatment effects have to be presumed as the product of net effect of increase in the content of some and decrease in the content of some other elements. This is especially proven in the present trial as application of silica sources have increased yield but reduced the content and uptake. In addition the use efficiency have also changed. As an example, sodium silicate increased the silica uptake but reduced Fe and Mn uptake, in increasing the grain and straw yield. This would mean that realised yield is not a function of any element but is one of combined effect.

Reduction in the uptake of any element whether associated or not with increased yields, can operate only by exclusion and / or dilution mechanisms operating at soil level and dilution mechanisms operating at the plant level. It appears that in the case of insoluble sources the influence may be upto soil rhizosphere level alone. These however require further detailed precision studies.

**Phasic progression in elemental composition and uptake and yield expression**

A closer scrutiny of the data on plant content of elements show diverse progressive changes with advancement in growth. K and S contents did not change from maximum tillering to panicle initiation but declines at flowering. Ca and Mg contents were subjected to not much change. Fe showed a progressive steep decline. Mn, $SiO_2$ and Zn tended to rise from panicle initiation to flowering Fe, Mn and Zn are elements required only in ppm levels. Decline in Fe may be the direct result of its lack of mobility and decreasing tendency of availability with continued submergence whereas increasing content of Mn and Zn may be a function of continued absorption or mobility or both. Stable levels of N, P, K may be the result of availability supported by application. Absence of significant differences between levels of K in content of N, P and K, between N and K in control VS rest and N and P between sources of silica at panicle initiation stage is

**Fig. 5. Effect of treatments on uptake of N, P and K (kg ha$^{-1}$)**



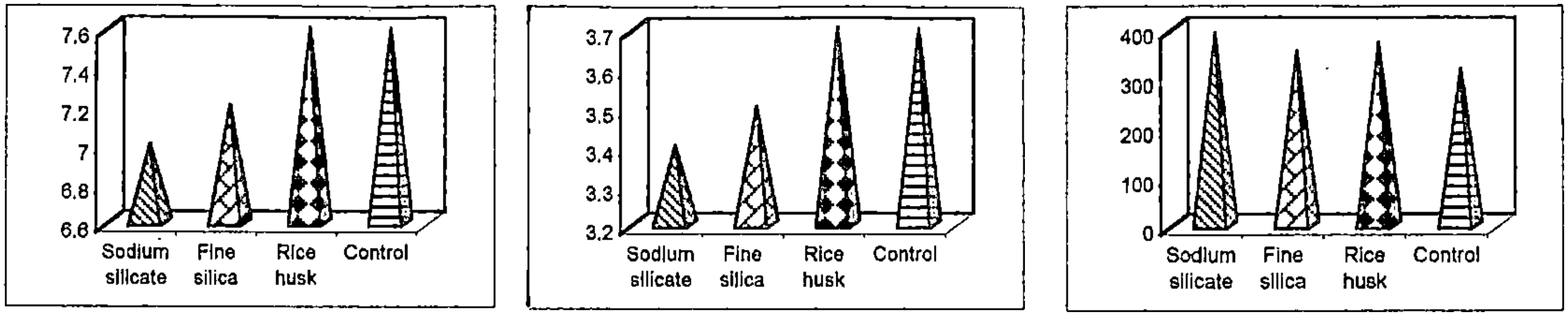
but significant variation of Mg, Mn and Fe due to treatment effect also evident. It would suggest that variation in N, P and K contents is not the cause of yield variation. Conversely it would also mean that the lowest content of these elements would be sufficient for the highest yield. These results therefore will imply that variation in plant content of non applied elements is the cause of yield variation. As such low productivity in the laterite soil, would mean a soil induced inhibition in the plant and that amelioration of inhibition will hold the way to higher yield.

Fe, Mn and Zn contents in the plant have been well above the upper critical level and in the toxic range (Yoshida, 1981) all through and the treatment effects have shown significant effect of varying extents in reducing them which was in corroboration with yield variation (Table 10). Sodium silicate has been the most efficient source and had given the highest yield. It had reduced Fe, Mn and Zn at maximum tillering and panicle initiation, increased productive tillers and floret number significantly over rice husk. Significant reduction in Fe by general treatment effect and levels of K, Zn by silica sources Fe and Mn by silica levels, followed by better translocation and grain weight would mean that these elements were involved in inhibited translocation as well. Similar results have also been reported by Bridgit (1999).

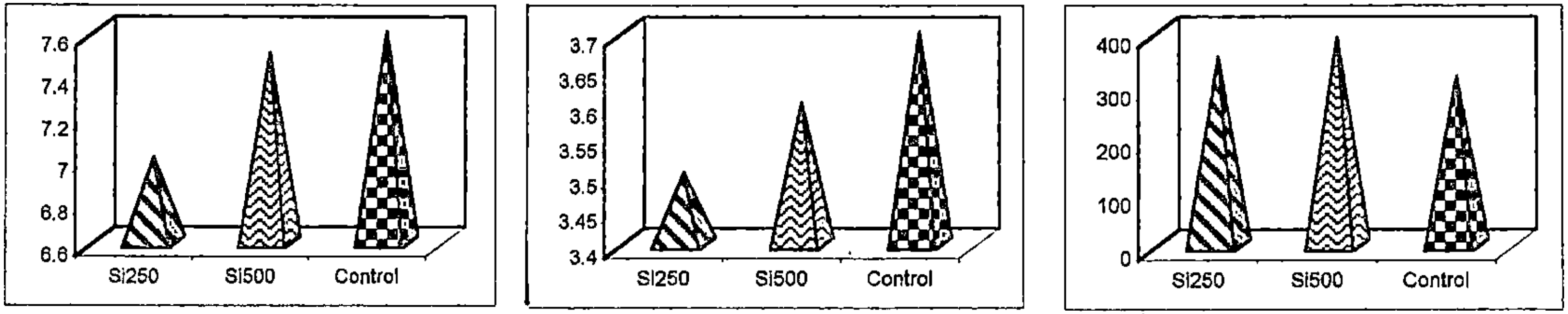
A perusal of the data on dry matter increase of both shoot and root between maximum tillering and panicle initiation (Table 7) and content and uptake of elements (Fig.5 and 6) in the corresponding stages will show that increase in dry matter production had been linked to the extent of reduction in the plant content of Fe, Mn and Zn. This is further confirmed by the uptake. Dry matter increase had been associated with reduced uptake. There was significant reduction of Fe, Mn, Ca and Mg contents due to sodium silicate application, which in turn reflected on yield. In other words dry matter increase had been a physiological effect in consonance with the agrobiological principle of Wilcose (1937). Conversely it implied that a higher content of Fe, Mn and Zn brought about an inhibition in physiological effect.

**Fig. 6. Effect of treatments on uptake of Fe, Mn and $SiO_2$ (kg $ha^{-1}$)**

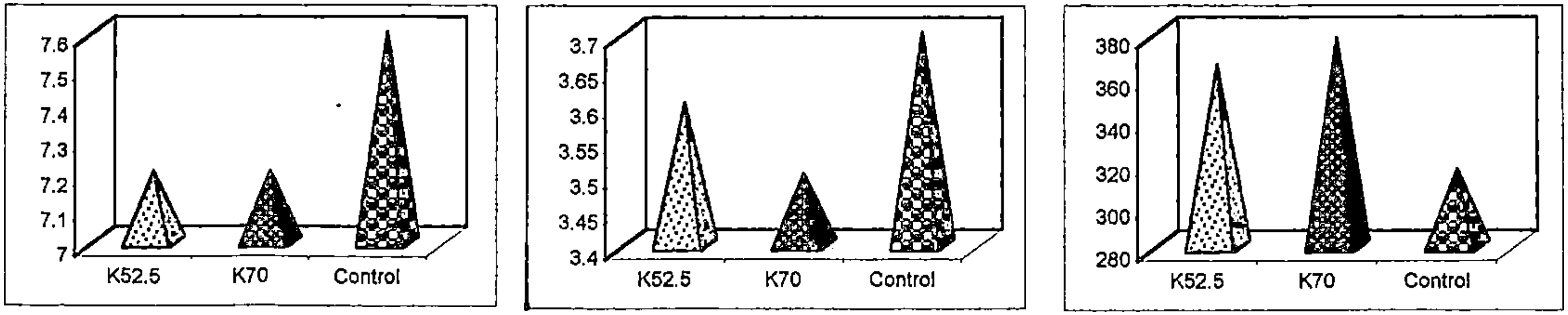
Iron | Manganese | Silicon




Effect of sources of silica




Effect of levels of silica




Effect of levels of K

Reduced contents and uptake of Fe, Mn and Zn by panicle initiation stage had naturally been an internal effect in the plant system brought about by the treatments. A comparatively lower content of $SiO_2$ at panicle initiation under sources and levels of silica (Table 17) and higher values at flowering (Table 21) would imply that the effect of treatments at panicle initiation stage were soil borne whereas translocation effects were plant borne. Possibly treatment effects were multi-dimensional.

A reduction in the plant content of Ca, Mg, Fe, Mn and Zn associated with near static levels of N, P, K but significant increase in use efficiency of N, P, K indirectly implies that ratios of N, P, K with these elements give a better clue in the analysis of yield limiting influences. A Perusal of the data (Tables 33 to 37) showed that all the treatments widened N/Fe, K/Fe, K/$SiO_2$ and Fe/$SiO_2$ ratios which too suggested that Fe was the primary yield limiting constraint and that silica was an efficient ameliorant, K effect was relatively low because it could affect only N/Fe and P/Fe ratios other than K.

*Two factor interaction effects*

A Perusal of the data on two factor interaction effects (Tables 15 to 32) showed that the effect of application of an element or its absorption by plant is not confined to that element alone but it affects other elements also. The results also have brought about that the effect is not uniform in nature or magnitude but varies with different elements.

Thus a change in the source of silica from sodium silicate to fine silica increased Ca, Fe and Zn by 6.1, 18.6 and 19.0 per cent. Whereas rice husk increased $SiO_2$ alone by 9.1 per cent at panicle initiation. Increase in the level of sodium silicate from 250 to 500 kg Si $ha^{-1}$ at flowering significantly reduced Fe and Mn content by 12.5 and 30.9 per cent respectively whereas fine silica and rice husk increased the Fe content by 11.9, 30.6 per cent. Variation in interaction appeared to be due to variation in reactivity consequent of variation in solubility and degradability. Yield variation due to sources therefore would appear to be due to variation in interaction effect.

A Perusal of the data in Tables 13 to 30 showed that the variable influences of sources and levels of silica on the content of other elements is further modified by K levels. Thus at the higher level of 70 kg K $ha^{-1}$ the reducing effect of sodium silicate on Ca, Fe and $SiO_2$ contents at flowering was not apparent. In the case of insoluble source of silica the reducing effect of silica on Fe and Ca was even reversed to significant increase in these levels. The observation is that yield improvement was linked to reduction in Fe, Mn and Zn contents and ineffectiveness of some of the treatment combinations of fine silica and rice husk may be because of this ineffectiveness of these sources to reduce the Fe, Mn and Zn content. These results also would mean that a failure to improve the yield by any of additive factor would be the effect of the interaction it creates. Thus the sodium silicate with 70 kg K $ha^{-1}$ has given the highest yield of 7300 kg because it had reduced the Fe and Mn contents of the plant at panicle initiation and Fe at flowering. Hypothetically it would mean that yield would have been still higher if some factor has reduced Fe and Zn at panicle initiation further. Possibly one agent or factor can not mitigate all the effects. This calls for a multicomponent management system to keep the levels of all elements within limits.

**Disease Resistance**

Data on the incidence of pests and diseases in Table 38 showed that general treatment effects as well as specific increase in the levels of silica has significantly reduced the incidence of pests. Variation in incidence among treatments would mean that the insect pests were there and treatment effects conferred resistance. Silica is known to give physical resistance (Takahashi, 1997) but the reduced silica content would tends to rule out the possibility of silica being the cause of reduced incidence.

Physiologically, resistance is achieved by the accelerated synthesis of phenols and O.D. Phenols to which may be related to S content. The failure of treatments to modify sulphur content possibly rules out the possibility for development of direct physiological resistance. These possibilities would narrow down the option to nutrient contents. Significant nutritional characteristics involved in the resistance appeared to be nutrient ratios viz., N/Fe, N/Mn, N/$SiO_2$, P/$SiO_2$ and Fe/$SiO_2$ i.e. a relative reduction in the plant content of Fe and Mn. Data on dry matter accumulation will show that high Fe and Mn were the factors involved in reduced growth. Thus the results would mean that vulnerability to pests had been the result of weakness of the host plant due to inhibited growth. Resistance to pest would appear to be the resistance to the inhibited growth brought by the treatments.

**Effect of treatments on soil nutritional characteristics**

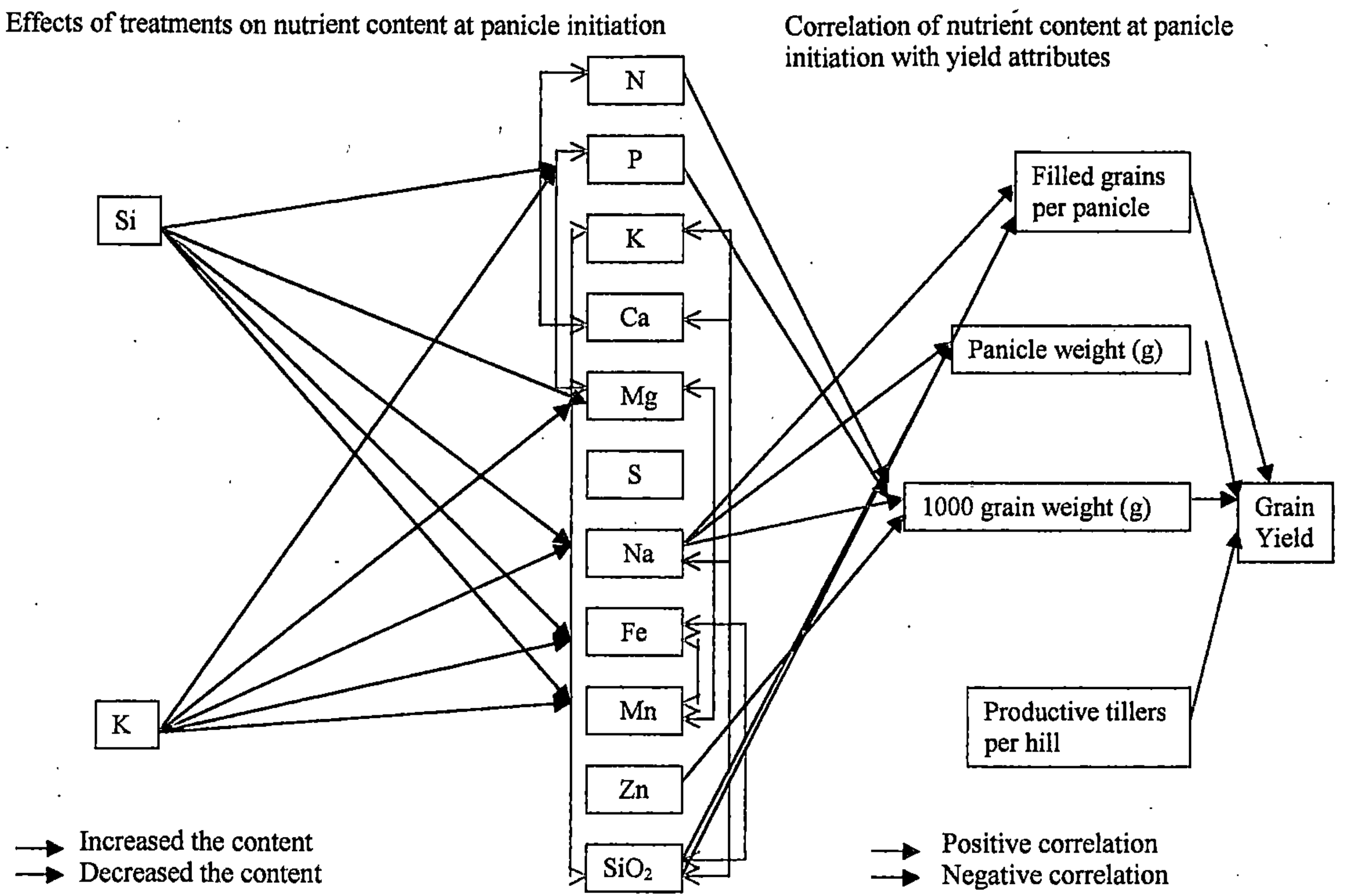
The most significant observation emanating from a comparative evaluation of the soil nutritional characteristics before and after cropping has been a heavy decline in organic carbon and nitrogen content of the soil after cropping (Table 39). Almost all the expressed soil nutritional characteristics should depend upon soil organic carbon, as otherwise soil will become a source and not medium for plant growth. Thus decline in soil organic carbon by treatment effect is a sign of soil degradation. A perusal of the data on N removal by crop along with the level of applied N will show that reduction in organic carbon content has been due to the favoured growth environment. The excess removal has ranged from 27 to 36 per cent, which could come only from humus break down. Maintenance of humus therefore will call for an addition of nutrients in tune with removal. The very same yardstick, applied to other major nutrients, will show that level of P shall be reduced to 1/3 and K has to be increased to 2.0 to 2.5 folds to compensate for removals. Possible causes of declining yield trends in permanent manurial trial in the state may include this also. Variation in other elements appears to be due to soil degradation.

**Influence of treatment components on terminal biometric pathway on yield through nutrition**

Yield of grain in rice is the terminal product of growth and development of the plant. The yield contributing components of the crop are productive tillers, which is decided at the panicle initiation stage. Number of productive tillers and number of florets per panicle are decided by the Carbohydrate reserves in the tillers one month before heading (Mureta, 1969). Results in the present study showed that the treatments of silica and K failed to affect it. All the other three attributes which contributed to yield variation in response to treatments were post flowering components. Thus the study showed that effect of K and silica in the present study had manifested in the later stages only. Carbohydrate reserves in the plant which decide the floret number is predominantly a function of metabolic use of nitrogen at that stage of development. Absence of inter relation of silica and K with nitrogen explain why productive tillers were not affected.

The data (Table 17) and Fig.7 also showed the mechanics of influence of k and silica on yield formation. The fact that both these elements have not significantly affected their contents would mean that yield improvement due to their application was not due to making up their deficiency. Their effect on yield was through modifying the contents of the other elements. K has reduced the contents of P, Mg, Fe and Mn and increased the yield while silica has reduced the contents of Mg, Fe and Mn. This would imply that their role had been regulating the yield inhibiting influences of P, Mg, Fe and Mn by reducing their absorption. The fact that both these elements have reduced Mg, Fe and Mn would mean that their effects are complementary and that these elements are compatible. Data on the uptake of K and $SiO_2$ (Table 22) showed significant increases in their uptake. Thus their absorption has stimulated growth and caused dilution of contents of these elements. Thus the role of the elements had been ameliorative of the crippled growth and development process passed on to the plant from the soil. Laterite soils are highly leached soils with an $SiO_2$ / $R_2O_3$ ratio of 1.32 and domination by

**Fig. 10.Terminal biometric path way on yield through nutrition**



hydrous oxides of Fe and Mn. It appeared therefore that the inhibiting effect of soil due to Mn and Fe is the product of weather soil interaction over time. Similar results have also been reported by Bridgit (1999).

The data further showed that plant content of Mg, Fe and Mn were positively interrelated. A change in one will be affecting the other. In the present study both K and silica affected Mg,Fe and Mn which confirm that they were complementary in this respect.

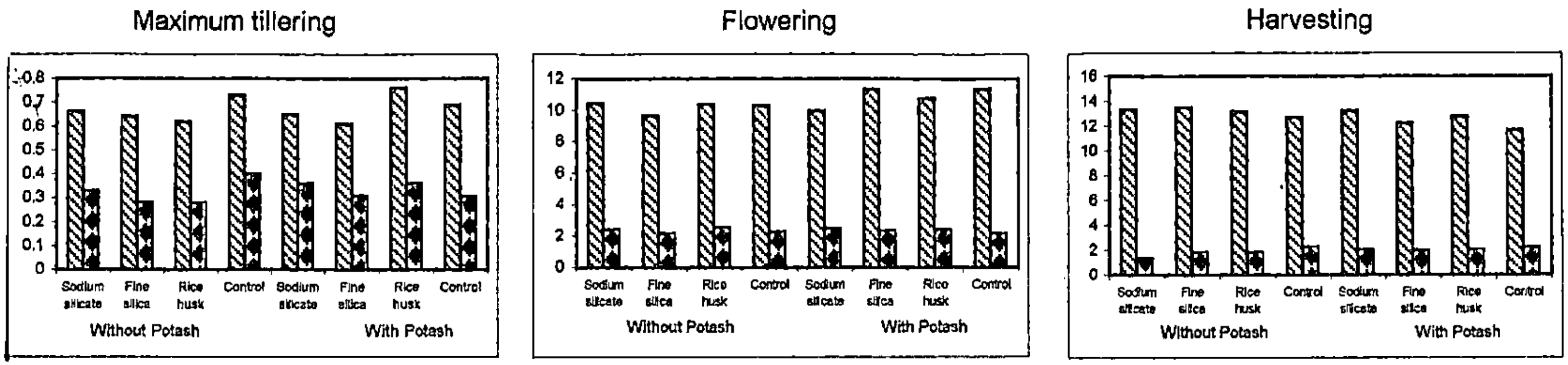
A closer perusal of the data will show that silica increased the yield not only by reducing the Mg, Fe and Mn but not increasing its content in the plant. The relationships of Si with yield components showed that its direct effect of its content on them had been negative. It would suggest a higher dose of silica itself could have nullified the positive of it on reducing Mg, Fe and Mn. Thus the present study appeared to be a 'specific level function of silica'. These data also imply that the source element can have two diametrically functions in the system depending upon levels of application. It would also mean that the net yield improvement due to silica had been the balance between its positive effect on yield by reducing the contents of Mg, Fe and Mn and its own negative direct effects on yield (Appendix vi). These data will define amelioration effect as an indirect positive effect obtained from an input.

**Residual crop**

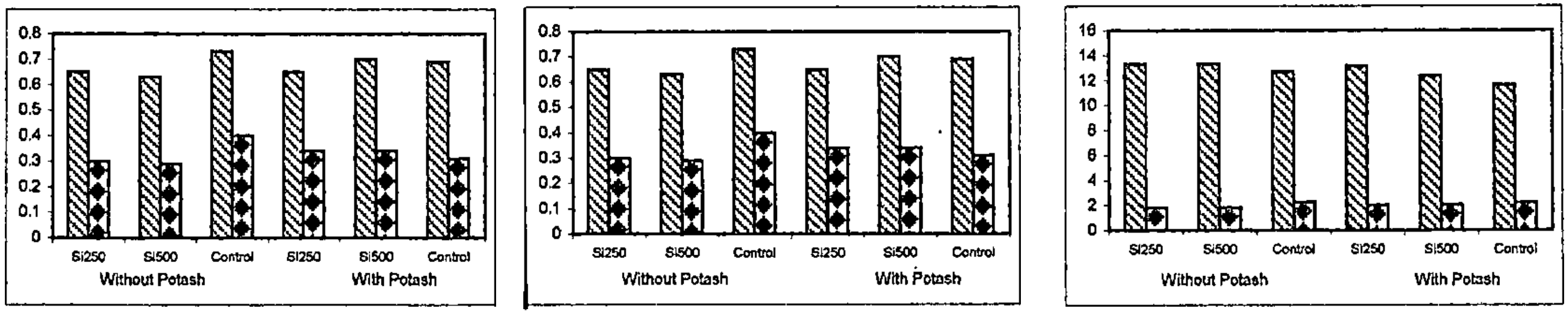
The residual effect of the treatments imposed during the first crop season, in the presence and absence of current season application of potash (Tables 40 to 78) is discussed in this section.

The general residual effect of the treatments increased the yield of grain by 571 kg $ha^{-1}$ in the absence of potash while the increase was 358 kg $ha^{-1}$ in the presence of applied potash. Though there was marginal improvement in panicle weight and number of filled grains per panicle in the treatment plots, as compared

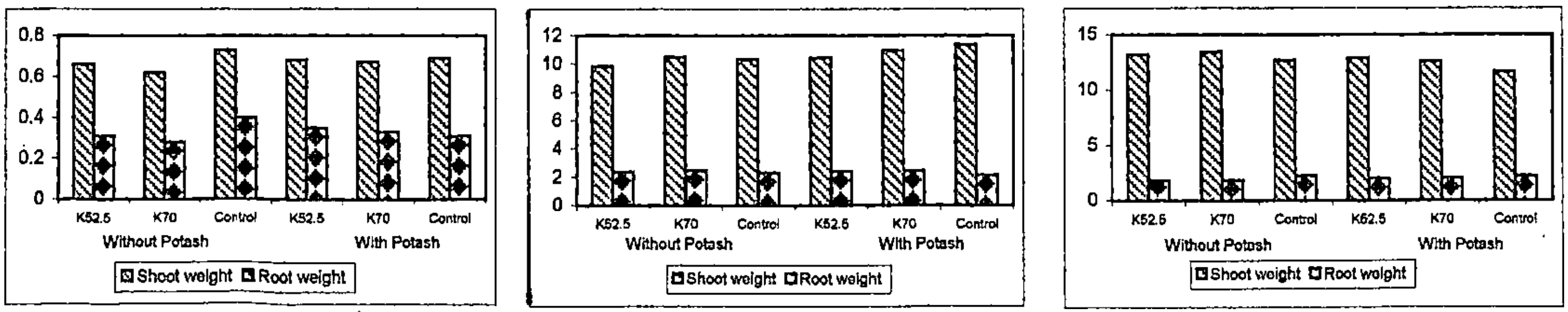
## Fig. 7. Residual effects of treatments on dry matter production (g/plant)




Residual effect of sources of silica




Residual effect of levels of silica




Residual effect of levels of K

to control, it did not reach the level of significance both in the presence and absence of applied potassium. The post panicle initiation increase in the number of total and productive tillers, but reaching the level of significance only in the absence of potash, is a major contributory factor for the increased yield. Increased photosynthetic assimilation was facilitated in the reproductive phase by an increased flag leaf length in the absence of potash and an increased flag leaf width in the presence of potash (Tables 40 to 47).

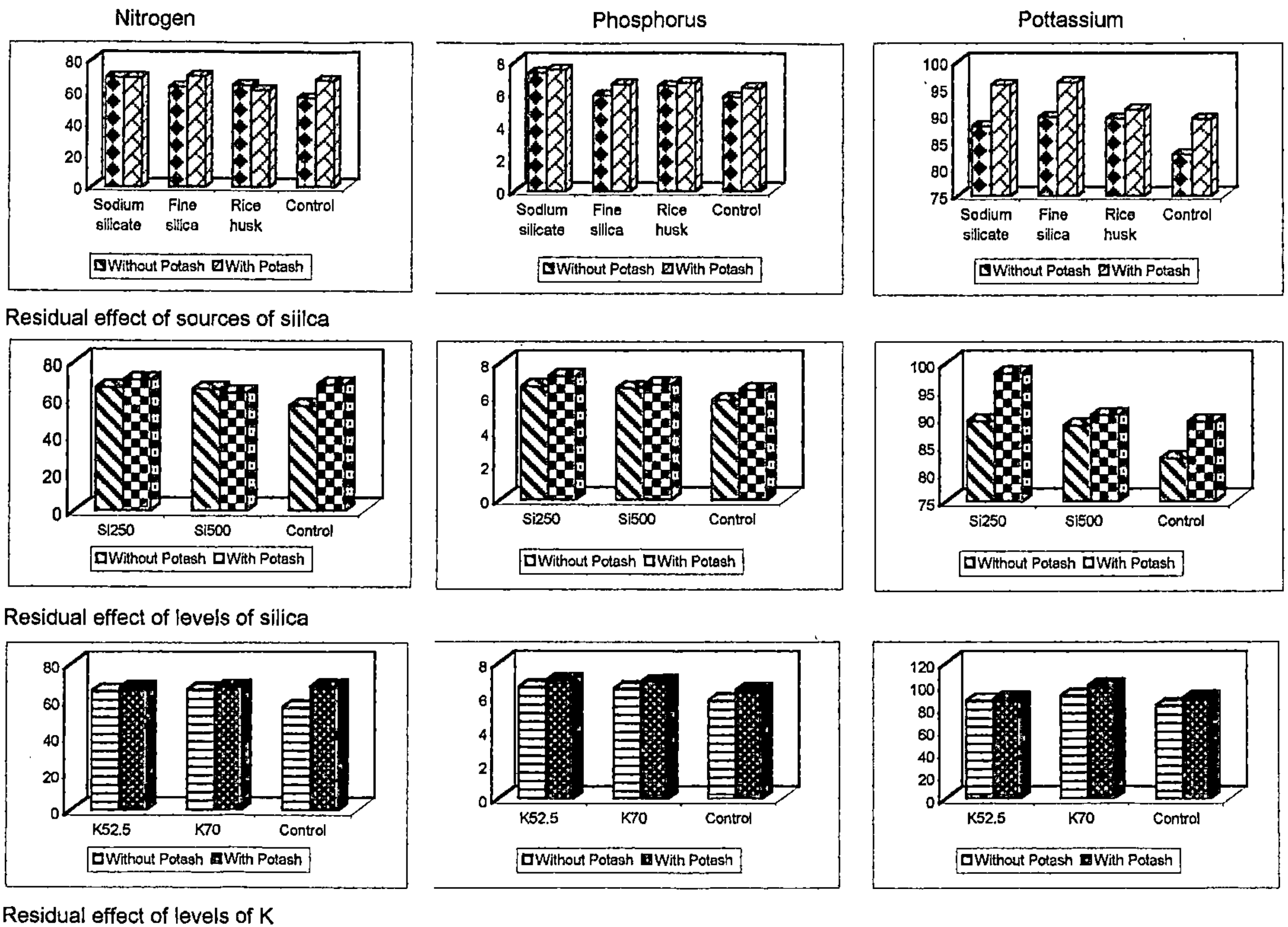
The treatments, increased the content of P and K from vegetative to harvest stages, but the effect reached the level of significance only in the presence of potash, with a resultant enhancement in their uptake, thus overcoming the problem of reduced availability of P and K in the laterite soils. Mengel and Kirkby (1982) reported low productivity in soils rich in Fe is due to depressed K absorption.

Even in the absence of current season potash application, the absolute residual effect of the treatments could lower the Mn content, throughout the growth stages of the crop, though significant only at early stages, thus favouring an improved nutrient balance and consequent yield increase.

**Residual effect of sources of silica**

The sources of silica exerted significant residual influence on the grain yield (Table 46) of the succeeding rabi crop but only in the presence of added potash. Sodium silicate was found to be the best source followed by fine silica and rice husk. Appreciable improvement in 1000 grain weight and reduction in chaffiness facilitated increased grain yield in sodium silicate applied plots. Improved vegetative growth in terms of plant height and tiller production at flowering indicated improved photosynthate production in this treatment (Fig.8).. Yamauchi and Winslow (1989) reported increased vegetative growth in terms of dry matter production due to application of sodium silicate. Though fine silica favoured enhanced straw yield, the grain yield was appreciably lower probably due

**Fig. 8. Residual effect of treatments on uptake of N, P and K (kg $ha^{-1}$)**



to the poor efficiency in the translocation of photosynthates, as reflected in lowest grain:straw ratio. But the translocation efficiency was found to be the highest in the sodium silicate applied plots. Takahashi *et al.* (1966) noticed that silicon promotes translocation of assimilates from the leaf blades to the panicle.

A closer scrutiny of the content and uptake (Tables 50 to 78) of the major and minor nutrients (Fig.9 and 10) indicated consistently reduced contents of Fe and Mn at the different growth stages from maximum tillering to harvest in the sodium silicate applied plots. The continued efficacy of sodium silicate through its residual influence in neutralizing the adverse effect of Fe and Mn in the laterite soils, facilitating increased yield, is thus clearly evident from the study. The efficacy of silica in reducing the adverse of effects of Mn and Fe were earlier reported by Horiguchi (1988) and Savant *et al.* (1997).

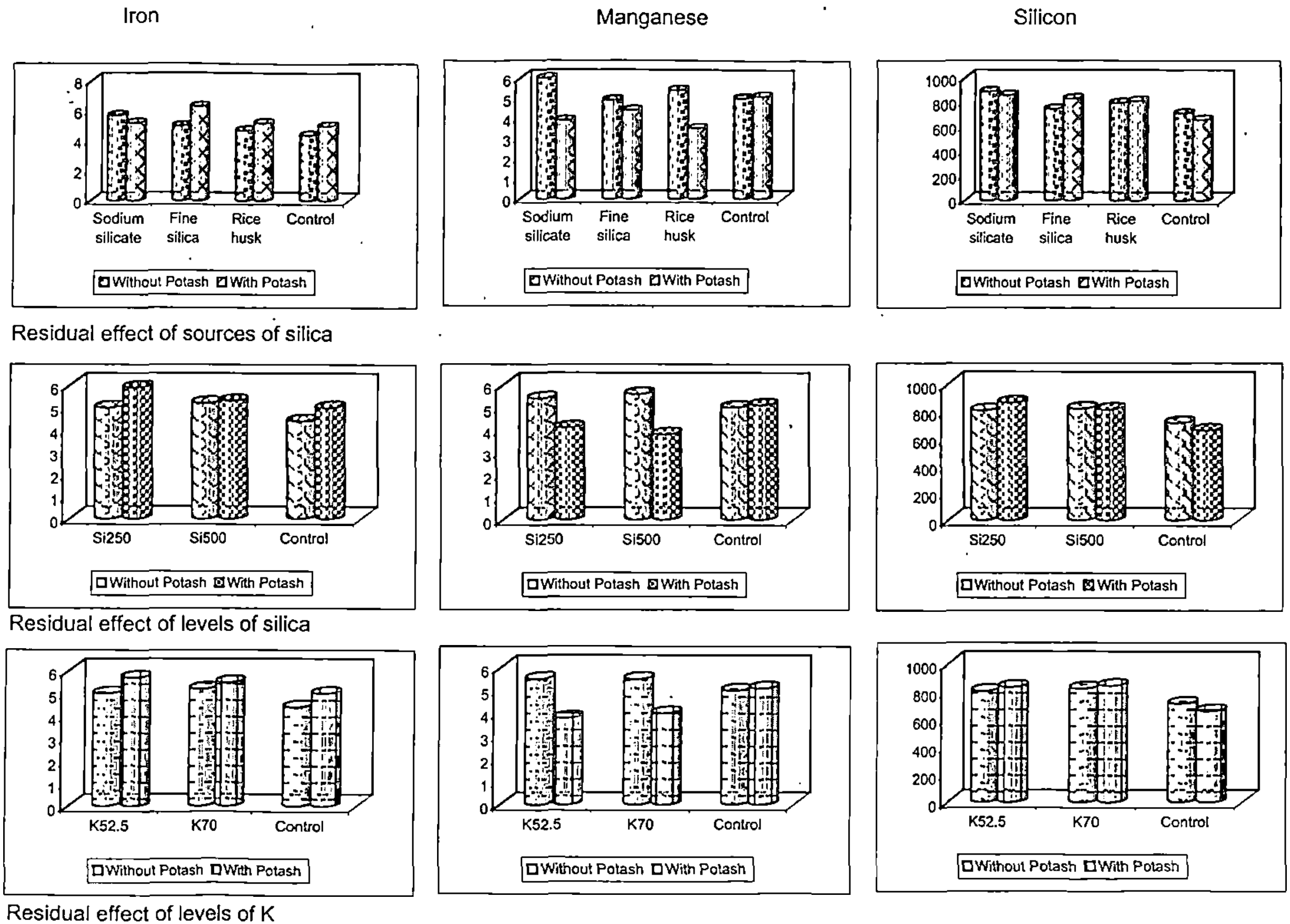
**Residual effect of levels of silica**

The residual effect of levels of silica was evident only in the presence of current season application of potash. Application of lower dose of silica in the preceding season increased the yield of grain and straw during rabi season. Lower levels of silica enhanced 1000 grain weight whereas the plant height was consistently higher at this level from maximum tillering to harvest stages. Residual effect of higher level of silica was found to enhance the content of silica throughout the growth period but it failed to improve the yield of the crop. The results suggest to limit the level of application of silica to 250 kg $ha^{-1}$ which is adequate to exploit the residual effect during the succeeding season.

**Residual effect of levels of potash**

Levels of potash failed to influence the grain yield of rice. Neither the residual effect nor the effect of current season application of potash was evident. However straw yield was significantly influenced by the current season application of potash. Potash content was found to be high at panicle initiation, flowering and

Fig. 10. Residual effects of treatments on uptake of Fe, Mn and $SiO_2$ (kg $ha^{-1}$)



harvest stages with current season application of increased dose of K. Content of Ca was found to be consistently high with increasing levels of potash in almost all the growth stages (Tables 50 to 76). The failure of the treatments to influence the content and uptake of other nutrients, reflecting unfavourably on the nutrient ratios (Appendix III) might have created imbalance among the nutrients in the plant system, leading to comparable yield at different levels of potash.

# SUMMARY

# 6. SUMMARY

The project entitled "Efficacy of silicon and potassium in the amelioration of iron in rice culture" was conducted during virippu and mundakan seasons of 1999-2000 at Agricultural Research Station, Mannuthy. The summary of results obtained from the study is presented below:

1. Combined effect of sources and levels of silica with levels of K increased the grain yield by 1000 kg $ha^{-1}$ over control.
2. The general treatment effect facilitated post panicle initiation increase in shoot weight and 1000 grain weight which contribute towards increased grain yield.
3. Among the three sources of silica, sodium silicate recorded the highest grain yield of 6644 kg $ha^{-1}$ followed by fine silica (6282 kg $ha^{-1}$) and rice husk (6113 kg $ha^{-1}$).
4. Increasing the level of silica from 250 to 500 kg $ha^{-1}$ increased the grain yield to the tune of 632 kg $ha^{-1}$.
5. Increasing the level of K application to 52.5 and 70 kg $ha^{-1}$, as against the package of practices recommendation of 35 kg K $ha^{-1}$ increased the grain yield by 951 and 1125 kg $ha^{-1}$, respectively.
6. The yield of straw significantly varied among the sources and levels of silica and levels of K. Among the sources, sodium silicate recorded the highest yield of 4128 kg $ha^{-1}$. Among the levels of silica the highest yield was recorded by 500 kg Si $ha^{-1}$ (3943 kg $ha^{-1}$).
7. The general treatment effect facilitated reduction in the Mn content at panicle initiation, and the content of Fe at panicle initiation and flowering stages.
8. A reduction in Fe content was observed at the flowering stage due to the general treatment effect and it contributed towards increased dry matter production at post-panicle initiation stages.

9. Content of Fe showed a decreasing trend from panicle initiation to flowering stage due to the general treatment effect whereas an increasing trend was noted in respect to control.
10. Sources of silica varied in their effect on content and uptake of K, Fe, Mn, Zn and $SiO_2$ at panicle initiation stage. Sodium silicate recorded the lowest content and uptake of K, Fe, Mn and $SiO_2$ whereas rice husk recorded highest content and uptake of K and $SiO_2$ while fine silica recorded the maximum content of Mn, Fe and Zn.
11. Application of 500 kg Si $ha^{-1}$ decreased the uptake of K at panicle initiation, but increased it at flowering stage.
12. Application of 70 kg K $ha^{-1}$ decreased the Fe content and uptake at panicle initiation and flowering stage.
13. Three factor interaction effects showed that the treatment receiving 500 kg Si $ha^{-1}$ as sodium silicate in combination with 70 kg K $ha^{-1}$ recorded the highest grain yield of 7306 kg $ha^{-1}$.
14 The combination which gave the highest grain yield of rice recorded reduced contents of Fe and Mn at panicle initiation and Fe at flowering.
15. Increased yield is found to be generally associated with reduced contents of Fe and Mn which suggest that these nutrients limit the productivity of rice in laterite soils.
16. Application of silica and higher levels of potash was found to ameliorate the limiting influences of Fe and Mn in laterite soils, enabling increased rice productivity.
17. The general treatment effect was found to reduce the incidence of major pests. Application of 500 kg Si $ha^{-1}$ reduced the incidence of stem borer and leaf folder but increased the incidence of gall midge.
18. During second crop season the residual effect of general treatments increased the grain yield by 571 and 358 kg $ha^{-1}$ in the absence and presence of applied potash respectively.

19. The residual effect of 250 kg Si $ha^{-1}$ recorded increased yield of grain to the tune of 215 kg $ha^{-1}$ over 500 kg Si $ha^{-1}$ in the presence of applied potash.
20. Application of 70 kg K $ha^{-1}$ in residual crop failed to influence the grain yield but increased the straw yield to 172 kg $ha^{-1}$.
21. Iron and Manganese content was reduced at different growth stages by the residual effect of sodium silicate during rabi season.
22. Residual effect of 500 kg Si $ha^{-1}$ was found to enhance the content of $SiO_2$ through out the growth period but it failed to improve the yield.
23. Calcium content was increased in the presence of K, but decreased in the absence of K at maximum tillering and flowering stage.

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*Originals not seen

# APPENDICES

## APPENDIX I

Weekly weather data during first crop season

| Week No. | Temperature (°C) | | | Relative humidity (%) | | Sunshine (hr $day^{-1}$) | Evaporation (mm $week^{-1}$) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean | Morning | Evening | | | |
| 22 | 29.8 | 23.5 | 26.7 | 96 | 75 | 5.0 | 21.5 | 143.2 |
| 23 | 29.1 | 22.8 | 26.0 | 94 | 81 | 4.8 | 22.7 | 134.7 |
| 24 | 28.4 | 22.7 | 25.5 | 95 | 81 | 1.1 | 17.3 | 170.9 |
| 25 | 29.6 | 23.2 | 26.4 | 95 | 76 | 5.1 | 20.6 | 114.8 |
| 26 | 30.9 | 23.0 | 27.0 | 92 | 67 | 8.9 | 26.4 | 21.6 |
| 27 | 29.6 | 23.1 | 26.4 | 95 | 80 | 3.7 | 20.5 | 114.7 |
| 28 | 29.0 | 22.9 | 26.0 | 96 | 76 | 3.1 | 18.0 | 124.6 |
| 29 | 26.9 | 22.8 | 24.9 | 97 | 92 | 3.2 | 12.6 | 326.5 |
| 30 | 27.7 | 22.7 | 25.2 | 95 | 83 | 1.1 | 13.0 | 182.8 |
| 31 | 28.7 | 23.3 | 26.0 | 95 | 84 | 2.7 | 17.1 | 194.1 |
| 32 | 29.5 | 23.7 | 26.6 | 95 | 74 | 5.2 | 20.8 | 121.5 |
| 33 | 30.6 | 24.1 | 27.4 | 93 | 69 | 7.5 | 24.7 | 8.9 |
| 34 | 30.0 | 23.6 | 26.8 | 93 | 69 | 6.9 | 25.1 | 3.2 |
| 35 | 30.0 | 23.6 | 26.8 | 93 | 71 | 5.3 | 20.6 | 7.1 |
| 36 | 30.0 | 23.2 | 26.6 | 93 | 67 | 4.9 | 18.7 | 18.3 |
| 37 | 31.0 | 23.0 | 27.0 | 92 | 65 | 8.1 | 27.6 | 10.1 |
| 38 | 32.6 | 23.4 | 28.0 | 90 | 56 | 8.5 | 31.0 | 0.0 |
| 39 | 32.9 | 23.8 | 28.4 | 90 | 60 | 6.4 | 28.2 | 0.0 |
| 40 | 30.5 | 23.1 | 26.8 | 93 | 71 | 4.8 | 19.6 | 80.5 |
| 41 | 31.5 | 23.6 | 27.6 | 95 | 75 | 6.8 | 23.8 | 185.7 |
| 42 | 29.5 | 23.3 | 26.4 | 95 | 80 | 2.9 | 16.8 | 161.6 |
| 43 | 31.3 | 23.5 | 27.4 | 93 | 74 | 5.5 | 19.6 | 38.8 |
| 44 | 29.6 | 22.7 | 26.2 | 96 | 73 | 6.2 | 20.3 | 41.9 |

# APPENDIX II

## Weekly weather data during second crop season

| Week No. | Temperature (°C) | | | Relative humidity (%) | | Sunshine (hr day$^{-1}$) | Evaporation (mm week$^{-1}$) | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean | Morning | Evening | | | |
| 45 | 31.4 | 22.1 | 26.8 | 87 | 62 | 7.8 | 22.4 | 1 |
| 46 | 31.1 | 22.1 | 26.6 | 74 | 46 | 10.1 | 26.6 | 0 |
| 47 | 31.1 | 23.5 | 27.3 | 79 | 62 | 6.3 | 29.4 | 0 |
| 48 | 31.9 | 23.7 | 27.8 | 76 | 55 | 8.7 | 36.4 | 0 |
| 49 | 31.8 | 21.6 | 26.7 | 79 | 49 | 9.4 | 34.3 | 0 |
| 50 | 31.8 | 21.6 | 27.2 | 78 | 50 | 8.1 | 31.5 | 0 |
| 51 | 31.4 | 22.6 | 27.0 | 72 | 47 | 8.7 | 44.8 | 0 |
| 52 | 31.4 | 22.6 | 27.4 | 68 | 43 | 8.8 | 49.0 | 0 |
| 1 | 32.2 | 23.4 | 28.0 | 71 | 45 | 9.6 | 48.5 | 0 |
| 2 | 31.9 | 23.8 | 28.1 | 74 | 51 | 7.6 | 45.2 | 0 |
| 3 | 33.5 | 24.3 | 28.0 | 78 | 37 | 9.5 | 43.6 | 0 |
| 4 | 33.8 | 22.4 | 28.0 | 82 | 39 | 9.9 | 41.5 | 0 |
| 5 | 33.7 | 22.1 | 26.8 | 74 | 41 | 10.1 | 49.7 | 0 |
| 6 | 33.2 | 19.9 | 28.1 | 92 | 57 | 7.2 | 31.8 | 0 |
| 7 | 34.2 | 23.0 | 28.6 | 80 | 44 | 9.3 | 42.0 | 0 |
| 8 | 33.2 | 22.6 | 27.9 | 90 | 59 | 8.7 | 33.0 | 0 |
| 9 | 33.9 | 23.8 | 28.9 | 81 | 47 | 8.0 | 44.1 | 4.6 |

## APPENDIX III

**Effects of treatments on nutrient ratios of rice at maximum tillering (without potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | $N/SiO_2$ | P/K | P/Fe | P/Mn | $P/SiO_2$ | K/Fe | K/Mn | $K/SiO_2$ | $Fe/SiO_2$ | $Mn/SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 18.24 | 1.32 | 10.23 | 139 | 1.00 | 0.65 | 0.56 | 7.60 | 0.260 | 7.74 | 105 | 0.76 | 0.098 | 0.0072 |
| Rest | 15.04 | 1.30 | 10.69 | 205 | 1.32 | 0.62 | 0.72 | 13.77 | 0.090 | 8.24 | 159 | 1.01 | 0.130 | 0.0064 |
| CD (0.05) | 1.86 | NS | NS | 22 | 0.15 | NS | 0.15 | 0.84 | 0.017 | NS | 19 | 0.11 | NS | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 14.09 | 1.25 | 12.50 | 212 | 1.11 | 0.62 | 0.89 | 15.08 | 0.080 | 9.90 | 169 | 0.88 | 0.091 | 0.0052 |
| Fine silica | 16.12 | 1.35 | 9.76 | 210 | 1.46 | 0.64 | 0.60 | 13.26 | 0.093 | 7.24 | 158 | 1.10 | 0.156 | 0.0070 |
| Rice husk | 14.92 | 1.29 | 9.82 | 193 | 1.39 | 0.62 | 0.66 | 12.98 | 0.092 | 7.58 | 149 | 1.06 | 0.143 | 0.0069 |
| CD (0.05) | 1.46 | 0.07 | 1.54 | 15 | 0.12 | NS | 0.10 | 0.57 | 0.010 | 1.39 | 13 | 0.08 | 0.024 | 0.0006 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 14.85 | 1.25 | 9.41 | 197 | 1.24 | 0.62 | 0.63 | 13.28 | 0.080 | 7.50 | 157 | 0.98 | 0.133 | 0.0062 |
| $Si_{500}$ | 15.23 | 1.34 | 11.98 | 213 | 1.40 | 0.63 | 0.80 | 14.26 | 0.092 | 8.99 | 160 | 1.05 | 0.126 | 0.0065 |
| CD (0.05) | NS | 0.05 | 1.25 | 12 | 0.08 | NS | 0.08 | 0.47 | 0.01 | 1.14 | NS | 0.06 | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 15.08 | 1.32 | 10.73 | 211 | 1.29 | 0.66 | 0.71 | 14.04 | 0.090 | 8.14 | 160 | 0.97 | 0.126 | 0.0061 |
| $K_{70}$ | 15.00 | 1.28 | 10.66 | 199 | 1.35 | 0.60 | 0.72 | 13.50 | 0.100 | 8.34 | 157 | 1.06 | 0.134 | 0.0066 |
| CD (0.05) | NS | NS | NS | 12 | NS | 0.06 | NS | 0.47 | NS | NS | NS | 0.06 | NS | 0.0005 |

**APPENDIX III**

**Effects of treatments on nutrient ratios of rice at maximum tillering (with potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | $N/SiO_2$ | P/K | P/Fe | P/Mn | $P/SiO_2$ | K/Fe | K/Mn | $K/SiO_2$ | $Fe/SiO_2$ | $Mn/SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 15.65 | 1.58 | 9.65 | 223 | 2.07 | 0.101 | 0.62 | 14.21 | 0.132 | 6.08 | 141 | 1.31 | 0.215 | 0.009 |
| Rest | 14.10 | 1.21 | 13.06 | 243 | 1.40 | 0.086 | 0.97 | 17.77 | 0.099 | 10.99 | 216 | 1.16 | 0.108 | 0.005 |
| CD (0.05) | NS | 0.12 | 1.34 | NS | 0.30 | 0.007 | 0.12 | 2.55 | 0.021 | 1.21 | 28 | NS | 0.032 | 0.002 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 12.11 | 1.13 | 15.13 | 247 | 0.99 | 0.093 | 1.26 | 20.74 | 0.083 | 13.52 | 224 | 0.90 | 0.067 | 0.004 |
| Fine silica | 16.27 | 1.27 | 9.05 | 206 | 1.89 | 0.078 | 0.56 | 12.69 | 0.118 | 7.16 | 163 | 1.51 | 0.110 | 0.008 |
| Rice husk | 13.93 | 1.22 | 15.01 | 276 | 1.32 | 0.088 | 1.09 | 19.88 | 0.095 | 12.29 | 227 | 1.08 | 0.089 | 0.005 |
| CD (0.05) | 0.97 | 0.10 | 0.91 | 27 | 0.23 | 0.006 | 0.08 | 1.73 | 0.016 | 0.82 | 19 | 0.21 | 0.022 | 0.001 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 14.03 | 1.23 | 13.33 | 256 | 1.47 | 0.088 | 0.97 | 18.37 | 0.104 | 10.88 | 209 | 1.21 | 0.128 | 0.005 |
| $Si_{500}$ | 14.18 | 1.19 | 12.79 | 231 | 1.33 | 0.085 | 0.97 | 17.18 | 0.093 | 11.11 | 200 | 1.12 | 0.116 | 0.006 |
| CD (0.05) | NS | NS | NS | 22 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 14.30 | 1.22 | 13.14 | 243 | 1.38 | 0.086 | 0.96 | 17.34 | 0.094 | 10.99 | 243 | 1.12 | 0.120 | 0.006 |
| $K_{70}$ | 13.90 | 1.20 | 12.98 | 243 | 1.42 | 0.087 | 0.98 | 18.20 | 0.103 | 10.99 | 243 | 1.20 | 0.124 | 0.006 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of rice at panicle initiation (without potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | $N/SiO_2$ | P/K | P/Fe | P/Mn | $P/SiO_2$ | K/Fe | K/Mn | $K/SiO_2$ | $Fe/SiO_2$ | $Mn/SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 11.46 | 0.90 | 9.79 | 120 | 0.54 | 0.38 | 0.87 | 10.63 | 0.05 | 11.08 | 136 | 0.61 | 0.055 | 0.0045 |
| Rest | 12.13 | 0.95 | 9.80 | 158 | 0.41 | 0.54 | 0.81 | 13.05 | 0.03 | 10.27 | 166 | 0.43 | 0.042 | 0.0027 |
| CD (0.05) | NS | NS | NS | 36 | 0.06 | 0.08 | NS | 2.15 | 0.01 | NS | NS | 0.07 | 0.005 | 0.0004 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 12.70 | 0.94 | 9.79 | 154 | 0.38 | 0.52 | 0.76 | 10.18 | 0.03 | 10.31 | 163 | 0.41 | 0.041 | 0.0026 |
| Fine silica | 11.54 | 0.98 | 10.28 | 161 | 0.43 | 0.56 | 0.90 | 13.73 | 0.04 | 10.55 | 166 | 0.44 | 0.042 | 0.0027 |
| Rice husk | 12.14 | 0.93 | 9.34 | 160 | 0.41 | 0.53 | 0.77 | 14.34 | 0.03 | 9.96 | 170 | 0.44 | 0.044 | 0.0026 |
| CD (0.05) | NS | NS | 0.73 | NS | NS | NS | 0.09 | 1.46 | NS | NS | NS | NS | NS | NS |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 11.85 | 0.91 | 8.97 | 151 | 0.41 | 0.51 | 0.76 | 13.59 | 0.04 | 9.85 | 166 | 0.45 | 0.046 | 0.0028 |
| $Si_{500}$ | 12.40 | 1.00 | 10.63 | 166 | 0.40 | 0.44 | 0.86 | 13.48 | 0.03 | 10.70 | 167 | 0.41 | 0.039 | 0.0025 |
| CD (0.05) | NS | 0.06 | 0.59 | NS | NS | 0.04 | 0.07 | NS | NS | NS | NS | 0.04 | 0.003 | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 11.58 | 0.95 | 9.40 | 151 | 0.40 | 0.55 | 0.81 | 13.00 | 0.04 | 9.98 | 161 | 0.42 | 0.043 | 0.0027 |
| $K_{70}$ | 12.67 | 0.96 | 10.21 | 166 | 0.41 | 0.53 | 0.80 | 13.01 | 0.03 | 10.57 | 172 | 0.43 | 0.042 | 0.0026 |
| CD (0.05) | 1.04 | NS | 0.59 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of rice at panicle initiation (with potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/$SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/$SiO_2$ | Fe/$SiO_2$ | Mn/$SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 12.8 | 0.95 | 11.90 | 101 | 0.76 | 0.075 | 0.94 | 7.94 | 0.060 | 12.55 | 107 | 0.80 | 0.064 | 0.008 |
| Rest | 10.9 | 0.73 | 9.45 | 141 | 0.75 | 0.068 | 0.88 | 13.00 | 0.070 | 12.98 | 191 | 1.04 | 0.081 | 0.006 |
| CD (0.05) | 1.4 | 0.06 | 2.09 | 24 | NS | NS | NS | 2.61 | 0.005 | NS | 34 | 0.12 | 0.011 | 0.001 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 11.4 | 0.75 | 9.78 | 155 | 0.77 | 0.067 | 0.87 | 13.89 | 0.068 | 12.91 | 203 | 1.03 | 0.081 | 0.005 |
| Fine silica | 10.4 | 0.68 | 9.37 | 125 | 0.78 | 0.066 | 0.91 | 12.00 | 0.075 | 13.88 | 184 | 1.15 | 0.083 | 0.006 |
| Rice husk | 10.8 | 0.76 | 9.20 | 142 | 0.71 | 0.071 | 0.85 | 13.10 | 0.066 | 12.15 | 187 | 0.93 | 0.080 | 0.005 |
| CD (0.05) | NS | 0.5 | NS | 16 | NS | NS | NS | NS | 0.004 | 1.29 | NS | 0.10 | NS | 0.001 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 11.5 | 0.74 | 8.74 | 134 | 0.77 | 0.064 | 0.76 | 11.73 | 0.067 | 11.97 | 183 | 1.06 | 0.089 | 0.006 |
| $Si_{500}$ | 10.2 | 0.73 | 10.16 | 147 | 0.73 | 0.071 | 0.99 | 14.27 | 0.072 | 13.99 | 200 | 1.02 | 0.074 | 0.005 |
| CD (0.05) | 0.8 | NS | 1.16 | 13 | NS | 0.004 | 0.07 | 1.30 | 0.003 | 1.06 | NS | NS | 0.006 | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 10.8 | 0.75 | 9.14 | 146 | 0.80 | 0.070 | 0.85 | 13.52 | 0.073 | 12.23 | 194 | 1.06 | 0.087 | 0.006 |
| $K_{70}$ | 10.9 | 0.71 | 9.76 | 136 | 0.71 | 0.066 | 0.91 | 12.48 | 0.066 | 13.73 | 189 | 1.01 | 0.076 | 0.006 |
| CD (0.05) | NS | 0.03 | NS | NS | 0.08 | NS | NS | NS | 0.003 | 1.06 | NS | NS | 0.006 | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of rice at flowering (without potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/SiO$_2$ | P/K | P/Fe | P/Mn | P/SiO$_2$ | K/Fe | K/Mn | K/SiO$_2$ | Fe/SiO$_2$ | Mn/SiO$_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 14.19 | 0.700 | 13.64 | 12.37 | 0.258 | 0.98 | 1.01 | 0.91 | 0.019 | 19.49 | 17.67 | 6.14 | 0.019 | 0.021 |
| Rest | 13.05 | 0.733 | 13.84 | 12.21 | 0.149 | 0.99 | 1.12 | 1.00 | 0.012 | 18.72 | 16.49 | 6.83 | 0.011 | 0.012 |
| CD (0.05) | NS | NS | NS | NS | 0.012 | NS | NS | NS | 0.004 | NS | 1.02 | NS | 0.001 | 0.001 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 10.53 | 0.778 | 14.62 | 13.76 | 0.151 | 0.97 | 1.39 | 1.33 | 0.015 | 18.79 | 17.78 | 9.06 | 0.011 | 0.011 |
| Fine silica | 14.25 | 0.691 | 13.77 | 11.03 | 0.144 | 0.99 | 1.00 | 0.80 | 0.010 | 19.94 | 15.96 | 9.34 | 0.011 | 0.013 |
| Rice husk | 14.37 | 0.756 | 13.12 | 11.84 | 0.152 | 10.01 | 0.96 | 0.87 | 0.011 | 17.44 | 15.73 | 9.38 | 0.012 | 0.013 |
| CD (0.05) | 2.68 | 0.058 | 0.89 | 0.62 | NS | NS | 0.19 | 0.15 | 0.003 | 1.70 | NS | NS | 0.001 | 0.001 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 12.39 | 0.724 | 13.25 | 11.99 | 0.146 | 0.98 | 1.14 | 1.05 | 0.013 | 18.38 | 16.59 | 9.35 | 0.011 | 0.012 |
| $Si_{500}$ | 13.71 | 0.760 | 14.43 | 12.43 | 0.152 | 1.00 | 1.09 | 0.95 | 0.011 | 19.06 | 16.39 | 9.17 | 0.011 | 0.012 |
| CD (0.05) | NS | NS | 0.73 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 12.61 | 0.740 | 13.87 | 11.99 | 0.147 | 0.95 | 1.15 | 1.00 | 0.012 | 18.83 | 16.21 | 9.39 | 0.011 | 0.012 |
| $K_{70}$ | 13.49 | 0.744 | 13.81 | 12.43 | 0.151 | 1.03 | 1.09 | 1.00 | 0.012 | 18.62 | 16.77 | 9.13 | 0.011 | 0.012 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of rice at flowering (with potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | $N/SiO_2$ | P/K | P/Fe | P/Mn | $P/SiO_2$ | K/Fe | K/Mn | $K/SiO_2$ | $Fe/SiO_2$ | $Mn/SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 12.94 | 0.70 | 13.20 | 13.76 | 0.304 | 0.054 | 1.02 | 1.07 | 0.023 | 18.86 | 19.66 | 0.434 | 0.023 | 0.023 |
| Rest | 9.53 | 0.54 | 13.18 | 14.36 | 0.273 | 0.057 | 1.39 | 1.52 | 0.029 | 24.64 | 26.81 | 0.512 | 0.021 | 0.020 |
| CD (0.05) | 0.92 | 0.07 | NS | NS | 0.029 | NS | 0.17 | 0.28 | 0.003 | 2.92 | 4.85 | 0.055 | 0.002 | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 9.12 | 0.56 | 14.10 | 15.44 | 0.287 | 0.062 | 1.55 | 1.72 | 0.032 | 25.19 | 27.28 | 0.516 | 0.021 | 0.020 |
| Fine silica | 10.08 | 0.54 | 12.48 | 14.48 | 0.276 | 0.053 | 1.24 | 1.44 | 0.027 | 23.36 | 27.20 | 0.518 | 0.022 | 0.019 |
| Rice husk | 9.38 | 0.51 | 12.97 | 13.16 | 0.255 | 0.055 | 1.39 | 1.40 | 0.027 | 25.41 | 25.93 | 0.502 | 0.020 | 0.020 |
| CD (0.05) | 0.72 | NS | 1.27 | NS | 0.023 | 0.003 | 0.11 | 0.19 | 0.002 | NS | NS | NS | 0.001 | NS |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 9.43 | 0.52 | 12.38 | 14.90 | 0.276 | 0.056 | 1.33 | 1.60 | 0.030 | 23.85 | 28.45 | 0.533 | 0.022 | 0.019 |
| $Si_{500}$ | 9.63 | 0.55 | 13.99 | 13.82 | 0.270 | 0.057 | 1.46 | 1.45 | 0.028 | 25.42 | 25.17 | 0.491 | 0.019 | 0.020 |
| CD (0.05) | NS | NS | 1.04 | NS | NS | NS | 0.09 | NS | NS | NS | 2.69 | 0.030 | 0.001 | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 9.23 | 0.55 | 13.11 | 14.83 | 0.257 | 0.059 | 1.43 | 1.62 | 0.028 | 24.13 | 27.08 | 0.473 | 0.020 | 0.018 |
| $K_{70}$ | 9.83 | 0.53 | 13.26 | 13.90 | 0.289 | 0.054 | 1.36 | 1.42 | 0.030 | 25.14 | 26.54 | 0.550 | 0.022 | 0.021 |
| CD (0.05) | 0.51 | NS | NS | NS | 0.016 | 0.002 | NS | 0.16 | 0.003 | NS | NS | 0.030 | 0.001 | 0.002 |

## APPENDIX III

**Effects of treatments on nutrient ratios of straw (without potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/$SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/$SiO_2$ | Fe/$SiO_2$ | Mn/$SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 8.23 | 0.33 | 8.15 | 6.63 | 0.036 | 0.04 | 0.99 | 0.81 | 0.006 | 24.63 | 20.08 | 0.108 | 0.004 | 0.005 |
| Rest | 9.76 | 0.34 | 7.36 | 6.61 | 0.035 | 0.04 | 0.74 | 0.66 | 0.005 | 22.16 | 19.87 | 0.106 | 0.005 | 0.005 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 0.13 | 0.12 | NS | NS | NS | NS | NS | NS |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 10.12 | 0.38 | 7.10 | 6.35 | 0.036 | 0.04 | 0.72 | 0.64 | 0.004 | 18.86 | 16.80 | 0.095 | 0.005 | 0.006 |
| Fine silica | 10.73 | 0.31 | 6.84 | 7.00 | 0.035 | 0.03 | 0.65 | 0.66 | 0.003 | 22.47 | 22.73 | 0.114 | 0.005 | 0.005 |
| Rice husk | 8.44 | 0.32 | 8.13 | 6.48 | 0.035 | 0.03 | 0.86 | 0.69 | 0.008 | 25.19 | 20.03 | 0.110 | 0.004 | 0.006 |
| CD (0.05) | NS | 0.03 | 0.60 | 0.47 | NS | NS | 0.09 | NS | NS | 1.90 | 1.25 | 0.005 | 0.001 | 0.001 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 9.25 | 0.33 | 7.34 | 6.65 | 0.035 | 0.04 | 0.75 | 0.67 | 0.006 | 22.59 | 20.52 | 0.108 | 0.005 | 0.005 |
| $Si_{500}$ | 10.27 | 0.35 | 7.38 | 6.57 | 0.036 | 0.03 | 0.74 | 0.65 | 0.004 | 21.75 | 19.26 | 0.105 | 0.005 | 0.006 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 1.02 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 9.94 | 0.35 | 7.58 | 6.60 | 0.036 | 0.04 | 0.78 | 0.67 | 0.004 | 22.13 | 19.12 | 0.104 | 0.005 | 0.006 |
| $K_{70}$ | 9.58 | 0.33 | 7.14 | 6.62 | 0.035 | 0.04 | 0.71 | 0.65 | 0.006 | 22.22 | 20.65 | 0.108 | 0.005 | 0.005 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | 0.07 | NS | NS | NS | 1.02 | 0.004 | NS | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of straw (with potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/$SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/$SiO_2$ | Fe/$SiO_2$ | Mn/$SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 9.79 | 0.448 | 9.11 | 6.73 | 0.155 | 0.046 | 0.93 | 0.69 | 0.017 | 20.29 | 15.00 | 0.346 | 0.017 | 0.023 |
| Rest | 10.79 | 0.363 | 6.71 | 7.08 | 0.131 | 0.035 | 0.69 | 0.67 | 0.013 | 18.59 | 19.62 | 0.362 | 0.021 | 0.019 |
| CD (0.05) | NS | NS | 1.09 | NS | 0.012 | 0.008 | 0.14 | NS | 0.003 | NS | 2.32 | NS | 0.003 | 0.002 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 12.55 | 0.399 | 7.84 | 7.71 | 0.136 | 0.033 | 0.65 | 0.65 | 0.011 | 19.82 | 19.46 | 0.344 | 0.018 | 0.018 |
| Fine silica | 10.88 | 0.356 | 5.87 | 6.46 | 0.132 | 0.034 | 0.61 | 0.61 | 0.013 | 16.60 | 18.10 | 0.372 | 0.023 | 0.021 |
| Rice husk | 8.93 | 0.334 | 6.43 | 7.06 | 0.124 | 0.038 | 0.80 | 0.80 | 0.014 | 19.34 | 21.31 | 0.372 | 0.020 | 0.018 |
| CD (0.05) | 2.46 | 0.019 | 0.74 | 0.61 | 0.009 | NS | 0.12 | 0.12 | NS | 1.55 | 1.57 | 0.019 | 0.002 | 0.002 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 10.60 | 0.369 | 6.97 | 7.35 | 0.136 | 0.036 | 0.71 | 0.71 | NS | 18.80 | 19.94 | 0.371 | 0.021 | 0.019 |
| $Si_{500}$ | 10.97 | 0.357 | 6.46 | 6.81 | 0.125 | 0.034 | 0.66 | 0.66 | 0.012 | 18.38 | 19.31 | 0.354 | 0.020 | 0.019 |
| CD (0.05) | NS | 0.013 | NS | 0.50 | 0.007 | NS | NS | NS | 0.013 | NS | NS | 0.013 | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 10.45 | 0.373 | 6.48 | 7.10 | 0.130 | 0.037 | 0.71 | 0.64 | 0.013 | 17.29 | 19.08 | 0.348 | 0.021 | 0.018 |
| $K_{70}$ | 11.12 | 0.353 | 6.95 | 7.06 | 0.132 | 0.033 | 0.66 | 0.65 | 0.012 | 19.89 | 20.17 | 0.377 | 0.019 | 0.019 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | 1.26 | NS | 0.013 | 0.002 | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of grain (without potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/$SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/$SiO_2$ | Fe/$SiO_2$ | Mn/$SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 11.17 | 2.29 | 20.71 | 20.71 | 0.387 | 0.206 | 1.87 | 1.87 | 0.036 | 9.04 | 9.04 | 0.169 | 0.019 | 0.019 |
| Rest | 10.08 | 2.30 | 23.21 | 23.06 | 0.303 | 0.231 | 2.34 | 2.32 | 0.030 | 10.16 | 10.12 | 0.133 | 0.013 | 0.013 |
| CD (0.05) | 0.95 | NS | NS | NS | 0.049 | NS | 0.36 | 0.32 | 0.005 | NS | NS | 0.021 | 0.002 | 0.002 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 9.21 | 2.36 | 22.77 | 23.04 | 0.281 | 0.256 | 2.49 | 2.52 | 0.031 | 9.83 | 9.93 | 0.120 | 0.012 | 0.012 |
| Fine silica | 10.82 | 2.34 | 24.45 | 23.72 | 0.354 | 0.216 | 2.28 | 2.20 | 0.033 | 10.62 | 10.28 | 0.154 | 0.015 | 0.015 |
| Rice husk | 10.21 | 2.21 | 22.42 | 22.42 | 0.274 | 0.220 | 2.24 | 2.24 | 0.027 | 10.16 | 10.16 | 0.124 | 0.012 | 0.012 |
| CD (0.05) | 0.75 | NS | NS | NS | 0.038 | 0.025 | NS | 0.22 | 0.004 | NS | NS | 0.016 | 0.002 | 0.002 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 10.15 | 2.34 | 24.24 | 24.24 | 0.318 | 0.234 | 2.44 | 2.44 | 0.032 | 10.44 | 10.44 | 0.136 | 0.013 | 0.013 |
| $Si_{500}$ | 10.00 | 2.26 | 22.19 | 21.88 | 0.288 | 0.227 | 2.23 | 2.19 | 0.029 | 9.96 | 9.80 | 0.129 | 0.013 | 0.013 |
| CD (0.05) | NS | NS | 1.53 | 1.65 | 0.027 | NS | 0.20 | 0.18 | 0.003 | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 9.97 | 2.34 | 22.81 | 22.99 | 0.308 | 0.237 | 2.32 | 2.34 | 0.031 | 9.85 | 9.92 | 0.133 | 0.014 | 0.013 |
| $K_{70}$ | 10.18 | 2.26 | 23.62 | 23.14 | 0.298 | 0.225 | 2.35 | 2.30 | 0.030 | 10.55 | 10.33 | 0.132 | 0.013 | 0.013 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## APPENDIX III

**Effects of treatments on nutrient ratios of grain (with potash)**

| Treatment | N/P | N/K | N/Fe | N/Mn | N/$SiO_2$ | P/K | P/Fe | P/Mn | P/$SiO_2$ | K/Fe | K/Mn | K/$SiO_2$ | Fe/$SiO_2$ | Mn/$SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 11.40 | 2.10 | 25.80 | 157 | 0.078 | 0.186 | 2.32 | 14.14 | 0.007 | 12.37 | 76 | 0.037 | 0.003 | 0.0005 |
| Rest | 9.43 | 1.92 | 26.16 | 191 | 0.064 | 0.207 | 2.86 | 20.68 | 0.007 | 13.81 | 100 | 0.034 | 0.003 | 0.0003 |
| CD (0.05) | 1.46 | NS | NS | 32 | 0.004 | 0.020 | 0.36 | 4.01 | NS | NS | 21 | 0.003 | NS | 0.0001 |
| *Sources of silica* | | | | | | | | | | | | | | |
| Sodium silicate | 8.00 | 1.76 | 27.15 | 172 | 0.063 | 0.222 | 3.41 | 21.75 | 0.008 | 15.33 | 97 | 0.036 | 0.002 | 0.0004 |
| Fine silica | 10.77 | 2.12 | 26.51 | 204 | 0.068 | 0.197 | 2.47 | 19.01 | 0.006 | 12.58 | 97 | 0.032 | 0.003 | 0.0003 |
| Rice husk | 9.52 | 1.87 | 24.81 | 197 | 0.061 | 0.202 | 2.70 | 21.27 | 0.007 | 13.51 | 107 | 0.033 | 0.003 | 0.0003 |
| CD (0.05) | 1.15 | 0.18 | NS | 22 | 0.003 | 0.017 | 0.25 | NS | 0.001 | 1.28 | NS | 0.002 | NS | 0.0001 |
| *Levels of silica* | | | | | | | | | | | | | | |
| $Si_{250}$ | 9.57 | 1.94 | 24.29 | 183 | 0.064 | 0.206 | 2.58 | 19.18 | 0.007 | 12.56 | 94 | 0.034 | 0.003 | 0.0004 |
| $Si_{500}$ | 9.28 | 1.89 | 28.02 | 199 | 0.064 | 0.208 | 3.14 | 22.18 | 0.007 | 15.05 | 107 | 0.034 | 0.002 | 0.0003 |
| CD (0.05) | NS | NS | 2.73 | NS | NS | NS | 0.20 | 2.22 | NS | 1.05 | 11 | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | | | | |
| $K_{52.5}$ | 9.31 | 2.05 | 26.04 | 188 | 0.065 | 0.223 | 2.87 | 20.50 | 0.007 | 12.76 | 92 | 0.032 | 0.003 | 0.0004 |
| $K_{70}$ | 9.55 | 1.78 | 26.27 | 194 | 0.063 | 0.190 | 2.87 | 20.86 | 0.007 | 14.85 | 109 | 0.036 | 0.003 | 0.0003 |
| CD (0.05) | NS | 0.13 | NS | NS | NS | 0.012 | NS | NS | NS | 1.05 | 11 | 0.002 | NS | NS |

# APPENDIX IV

**Effects of Treatments on nutrient uptake (kg ha$^{-1}$) at harvest**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 96.1 | 11.0 | 111.5 | 12.2 | 10.2 | 12.0 | 56.5 | 7.6 | 3.7 | 0.44 | 315.8 |
| Rest | 108.6 | 13.6 | 118.6 | 13.0 | 10.7 | 11.4 | 49.8 | 7.2 | 3.5 | 0.41 | 371.1 |
| CD (0.05) | 9.9 | 1.2 | NS | 0.5 | 0.5 | NS | 4.6 | NS | NS | 0.02 | 34.0 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 116.5 | 14.8 | 123.1 | 13.5 | 11.5 | 10.9 | 57.8 | 7.0 | 3.4 | 0.42 | 389.9 |
| Fine silica | 107.0 | 13.3 | 111.1 | 12.6 | 10.1 | 12.0 | 46.7 | 7.2 | 3.5 | 0.39 | 352.7 |
| Rice husk | 102.3 | 12.6 | 121.7 | 12.9 | 10.6 | 11.4 | 44.9 | 7.6 | 3.7 | 0.42 | 370.6 |
| CD (0.05) | 6.7 | 0.7 | 5.2 | 0.3 | 0.3 | NS | 3.1 | 0.3 | 0.2 | 0.01 | 23.1 |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 102.5 | 13.0 | 113.8 | 12.4 | 10.7 | 11.5 | 47.3 | 7.0 | 3.5 | 0.39 | 352.7 |
| $Si_{500}$ | 114.8 | 14.2 | 123.5 | 13.7 | 11.3 | 11.4 | 52.3 | 7.5 | 3.6 | 0.43 | 389.4 |
| CD (0.05) | 5.5 | 0.6 | 4.3 | 0.3 | 0.3 | NS | 2.6 | 0.2 | NS | 0.01 | 18.9 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 105.5 | 13.1 | 119.2 | 13.2 | 10.7 | 11.9 | 50.4 | 7.2 | 3.6 | 0.41 | 364.8 |
| $K_{70}$ | 111.8 | 13.0 | 118.0 | 12.9 | 10.7 | 11.0 | 49.2 | 7.2 | 3.5 | 0.41 | 377.4 |
| CD (0.05) | 5.5 | 0.6 | NS | NS | NS | 0.9 | NS | NS | NS | NS | NS |

**APPENDIX V**

**Effects of Treatments on nutrient uptake (kg ha$^{-1}$) at harvest (without potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 56.2 | 5.8 | 82.7 | 9.0 | 9.3 | 7.8 | 45.6 | 4.4 | 5.0 | 0.24 | 714.0 |
| Rest | 65.6 | 6.6 | 89.0 | 10.7 | 10.6 | 9.3 | 44.0 | 5.1 | 5.5 | 0.23 | 813.2 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 69.1 | 7.3 | 88.0 | 12.2 | 11.4 | 10.8 | 53.7 | 5.7 | 6.0 | 0.24 | 890.4 |
| Fine silica | 63.2 | 5.9 | 89.7 | 9.6 | 10.0 | 8.8 | 39.6 | 5.0 | 4.9 | 0.23 | 749.3 |
| Rice husk | 64.4 | 6.5 | 89.4 | 10.2 | 10.4 | 8.2 | 39.6 | 4.7 | 5.4 | 0.24 | 800.0 |
| CD (0.05) | NS | 0.6 | NS | 1.5 | NS | 1.1 | 7.7 | 0.5 | 0.7 | NS | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 66.1 | 6.6 | 89.4 | 10.6 | 10.4 | 9.0 | 43.6 | 5.0 | 5.4 | 0.23 | 805.8 |
| $Si_{500}$ | 65.1 | 6.5 | 88.6 | 10.8 | 10.8 | 9.5 | 45.1 | 5.2 | 5.6 | 0.25 | 820.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 65.2 | 6.6 | 86.9 | 10.8 | 10.5 | 9.3 | 43.5 | 5.0 | 5.5 | 0.23 | 803.8 |
| $K_{70}$ | 66.0 | 6.5 | 91.2 | 10.6 | 10.6 | 9.3 | 43.1 | 5.2 | 5.5 | 0.25 | 822.6 |
| CD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## APPENDIX V

**Effects of Treatments on nutrient uptake (kg $ha^{-1}$) at harvest (with potash)**

| Treatments | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 67.6 | 6.4 | 89.3 | 12.0 | 10.5 | 8.5 | 31.6 | 5.0 | 5.1 | 0.22 | 659.6 |
| Rest | 66.8 | 7.9 | 94.3 | 11.5 | 9.6 | 8.5 | 22.0 | 5.6 | 3.9 | 0.21 | 837.8 |
| CD (0.05) | NS | NS | 3.2 | 0.3 | 0.5 | NS | 2.2 | 0.5 | 0.3 | NS | 48.8 |
| *Sources of silica* | | | | | | | | | | | |
| Sodium silicate | 69.2 | 7.5 | 95.7 | 11.5 | 9.6 | 8.9 | 22.7 | 5.2 | 3.9 | 0.23 | 861.4 |
| Fine silica | 69.9 | 6.6 | 96.2 | 12.5 | 9.8 | 8.5 | 22.7 | 6.3 | 4.4 | 0.22 | 835.0 |
| Rice husk | 61.2 | 6.7 | 91.1 | 10.6 | 9.5 | 8.1 | 20.6 | 5.2 | 3.5 | 0.19 | 817.0 |
| CD (0.05) | 3.0 | 0.4 | 2.2 | 0.2 | NS | 0.4 | NS | 0.3 | 0.2 | 0.01 | NS |
| *Levels of silica* | | | | | | | | | | | |
| $Si_{250}$ | 70.2 | 7.2 | 98.1 | 12.1 | 9.9 | 8.6 | 22.4 | 5.9 | 4.1 | 0.22 | 863.1 |
| $Si_{500}$ | 63.3 | 6.7 | 90.5 | 11.0 | 9.4 | 8.5 | 21.5 | 5.3 | 3.8 | 0.21 | 812.6 |
| CD (0.05) | 2.5 | 0.3 | 1.8 | 0.2 | 0.3 | NS | NS | 0.3 | 0.2 | NS | 27.1 |
| *Levels of Potash* | | | | | | | | | | | |
| $K_{52.5}$ | 66.4 | 7.0 | 88.5 | 11.4 | 9.6 | 8.2 | 23.8 | 5.7 | 3.8 | 0.21 | 832.8 |
| $K_{70}$ | 67.1 | 6.9 | 100.2 | 11.6 | 9.7 | 8.9 | 20.1 | 5.5 | 4.0 | 0.22 | 842.8 |
| CD (0.05) | NS | NS | 1.8 | NS | NS | 0.3 | 1.2 | NS | NS | NS | NS |

## APPENDIX VI

Correlation coefficients of nutrient content at panicle initiation and yield attributes of rice

| | Panicle weight (g) | Filled grains (No.) | 1000 grain weight (g) | Productive tillers per hill | N | P | K | Ca | Mg | S | Na | Fe | Mn | Zn | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 0.409* | 0.255 | 0.519* | -0.025 | 1.000 | | | | | | | | | | |
| P | -0.016 | 0.051 | 0.323* | 0.051 | 0.135 | 1.000 | | | | | | | | | |
| K | -0.260 | -0.268 | -0.137 | -0.288 | -0.022 | -0.117 | 1.000 | | | | | | | | |
| Ca | -0.307 | -0.256 | -0.162 | -0.272 | 0.327* | -0.083 | 0.275 | 1.000 | | | | | | | |
| Mg | -0.219 | 0.061 | 0.025 | -0.106 | 0.152 | 0.342* | -0.012 | 0.491* | 1.000 | | | | | | |
| S | 0.050 | 0.186 | 0.007 | 0.125 | -0.006 | 0.154 | -0.145 | -0.300 | 0.178 | 1.000 | | | | | |
| Na | 0.551* | 0.632* | 0.330* | 0.312 | -0.067 | -0.008 | -0.653* | -0.639* | -0.337* | 0.146 | 1.000 | | | | |
| Fe | 0.025 | -0.186 | 0.047 | 0.083 | 0.009 | 0.068 | 0.284 | 0.298 | 0.304 | -0.018 | -0.343* | 1.000 | | | |
| Mn | -0.224 | -0.169 | -0.290 | 0.197 | -0.023 | 0.164 | -0.112 | 0.224 | 0.391* | 0.137 | -0.260 | 0.429* | 1.000 | | |
| Zn | -0.293 | -0.313 | -0.379* | 0.041 | -0.259 | 0.003 | -0.015 | 0.096 | -0.004 | 0.204 | -0.186 | -0.233 | -0.091 | 1.000 | |
| $SiO_2$ | -0.442* | -0.431* | -0.200 | -0.235 | 0.131 | 0.164 | 0.556* | 0.565* | 0.490* | 0.129 | -0.819* | 0.380* | 0.300 | 0.088 | 1.000 |

* Significant at 5% level

# EFFICACY OF SILICON AND POTASSIUM IN THE AMELIORATION OF IRON IN RICE CULTURE

By

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## ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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# ABSTRACT

The study entitled "Efficacy of silicon and potassium in the amelioration of iron in rice culture" was carried out during virippu and mundakan seasons of 1999-2000 at Agricultural Research Station, Mannuthy, with the objective to evaluate the efficacy of silicon and potassium in ameliorating the stress influences of excess iron on rice productivity in laterite soils as well as to characterise their influences on growth and yield of rice.

Combined application of sources and levels of silica with levels of K increased the grain yield by 1000 kg ha$^{-1}$ over control. Among the three sources of silica sodium silicate recorded the highest grain yield of 6644 kg ha$^{-1}$ followed by fine silica (6282 kg ha$^{-1}$) and rice husk (6113 kg ha$^{-1}$).

Increasing the level of K application to 52.5 and 70 kg ha$^{-1}$, as against the package of practices recommendation of 35 kg K ha$^{-1}$, increased the grain yield by 951 and 1125 kg ha$^{-1}$, respectively. The yield of straw significantly varied among the sources and levels of silica and levels of K and sodium silicate recorded the highest yield of 4128 kg ha$^{-1}$.

Content and uptake of Fe showed a decreasing trend from panicle initiation to flowering stage where as an increasing trend was noted in respect of $SiO_2$ due to the general treatment effect.

Three factor interaction effect showed that the treatment receiving 500 kg Si ha$^{-1}$ as sodium silicate in combination with 70 kg K ha$^{-1}$ recorded the highest yield of 7306 kg ha$^{-1}$ and it also recorded reduced contents of Fe and Mn at panicle initiation and Fe at flowering.

During rabi season the residual effect of general treatments increased the grain yield by 571 and 358 kg ha$^{-1}$ in the absence and presence of applied potash.

Iron and Manganese content was reduced at different growth stages by the residual effect of sodium silicate during rabi season. The residual effect of 500 kg Si $ha^{-1}$ was found to enhance the content of $SiO_2$ throughout the growth period but it failed to improve the yield.

From the study it could be concluded that the increased yield was generally associated with reduced contents of Fe and Mn which suggest that these nutrients limit the productivity of rice in laterite soils and application of silica and higher levels of potash was found to ameliorate the limiting influences of Fe and Mn, enabling increased rice productivity.