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AGRICULTURAL APPLICATION OF RICE MILL WASTES AS A SUBSTITUTION OF POTASH FERTILIZER IN POTATO (Solanum tuberosum) CULTIVATION

A. Dutta, S. Gupta[*1] N.K. Mondal[2]
[*1]Department of Environmental Science; The University of Burdwan; Burdwan, West Bengal.

KEYWORDS: Effluent; rice husk ash; potato; biochemical constituents; yield.

ABSTRACT
Rice mills are major concern of pollution in Burdwan district, West Bengal with the generation of huge quantity of effluents and rice husk ash as wastes. The effluent contains 298 mg/L potassium whereas the ash contains 180 kg/ha potassium and 2.5 - 3.2% of organic carbon. Potato requires significant amount of potassium during cultivation. So the present research is formulated in order to apply the aforementioned wastes as a supplement of potash based chemical fertilizer. Entire experiments are conducted in a randomized block designed agricultural field with the span of three years (2007 – 2009). The first two year experiments are mainly focused in screening out of the optimum dose of effluent and rice husk ash with respect to maximum yield of tubers. Third year experiment is mainly confined to the reduction of potash based chemical potassium fertilizer along with the application of conventional N, P fertilizer, 100% effluent and 600kg/15m^2 rice husk ash. Outcome reveals that 40% reduction of potash based chemical fertilizer gives rise to maximum yield and improved biochemical constituents of potato tubers.

INTRODUCTION
With increasing global population the gap between the supply and demand of water is reaching to such an alarming level that in some part of the world it is pausing thread to human existence. Growing scarcity of high quality fresh water directly affects the developmental processes including agricultural output. Scientists around the globe are working on new ways of conserving water. The reuse of effluent by irrigation can make a significant contribution to the integrated management of our water resources (US EPA, 2004). It can play prominent role to maintain the crop yield as the nation is looking forward for second Green Revolution for their scarcity of food.

Rice Mill industries have been placed in the category of highly polluting industry within the district by the Pollution Control Board, Government of West Bengal. Most of the industries are placed away from the main town but very adjacent to the outback areas and villages to facilitate their raw material supply. In Rice Mills wet processes like paddy parboiling, circulation require large volume of fresh water. After the process is over the water becomes effluent. In the district the volume of the water produced everyday is about 400 lakhs liters. The Rice Mills also produces nearly 3000 tons of fly ash every day. The disposal of this effluent and rice husk ash is a major problem faced by the industries, due to production of high volume effluent and ash with very limited space for land based treatment and disposal facilities. Moreover unplanned disposal of these by products give rise to eutrophication of local water bodies as well as air pollution problem. On the other hand these Rice Mill wastes are also resources that can be applied for productive uses since they contain nutrients that have the potentiality for use in agriculture (Mittra et al., 2003). The utilization of Rice Mill wastes as 'soil amendment and alternative sources of irrigation' has generated interest in recent time. Most crops have higher potential yield with waste water irrigation; reduce the need for chemical fertilizer, resulting in net cost savings to farmers. So it is an important aspect to understand the specificity of crop- effluent relationship for their proper application in irrigation practice (Hussain et al., 2001).

Potato is an economical food and it provides a source of low cost energy to the human diet. It contains about 20.6 % carbohydrates, 2.1% protein, 0.3 % fat, 1.1 % crude fibre and 0.9 % ash. It also contains a good amount of essential amino acids. Potatoes are cultivated over an area of 19.3 million hectares in 150 countries of the world with a total production of 308 million tons. Potato requires good balance of N: P: K in soil and huge amount of water for its irrigation during 90 days of cultivation. As potato is a winter crop farmers are used apply ground water for the irrigation in the field, which is practically depletes the ground water resource. So considering the nutritive value and available quantity of both of the rice ash and effluent the present investigation was undertaken to evaluate the applicability of those by products as a substitution of potassium fertilizer for sustainable soil health and potato production.

STUDY AREA
Burdwan district is one of the highest potato producing provinces within the state of West Bengal. Here potato is considered as the second most staple food after rice. Jupiter Rice Mill (23°12´52.11˝N and 87°56´12.82˝E) and its

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adjacent agricultural land, situated at Saktigarh area of Burdwan district and at the side of National Highway-2, was selected for the present study (Fig 1). This rice mill produces rice mainly from the paddy verity of Swarna mansuri (BPT5204) and IR36 and produces~60000 liters of effluent/day. Effluents are disposed at the northern side of the factory. Experimental field (area 2000 m^2) is chosen just 20 m away from the mill boundary in order to facilitate the transportation of effluent and the rice husk ash. Entire experiment is carried out in Randomize Block Design (RBD) pattern with a total span of four consecutive years (2007 – 2010). A 30 m^3 tank was made at the north-east corner of the rice mill for storage and cooling down of effluent before applying as irrigation water. Average rainfall during experimental time span is 0.0 mm to 0.55 mm and maximum and minimum winter temperature ranges from 24.5 ℃ - 29.3 ℃ and from 14.1℃ - 17.4 ℃ respectively. Humidity ranges from 37% - 68%.

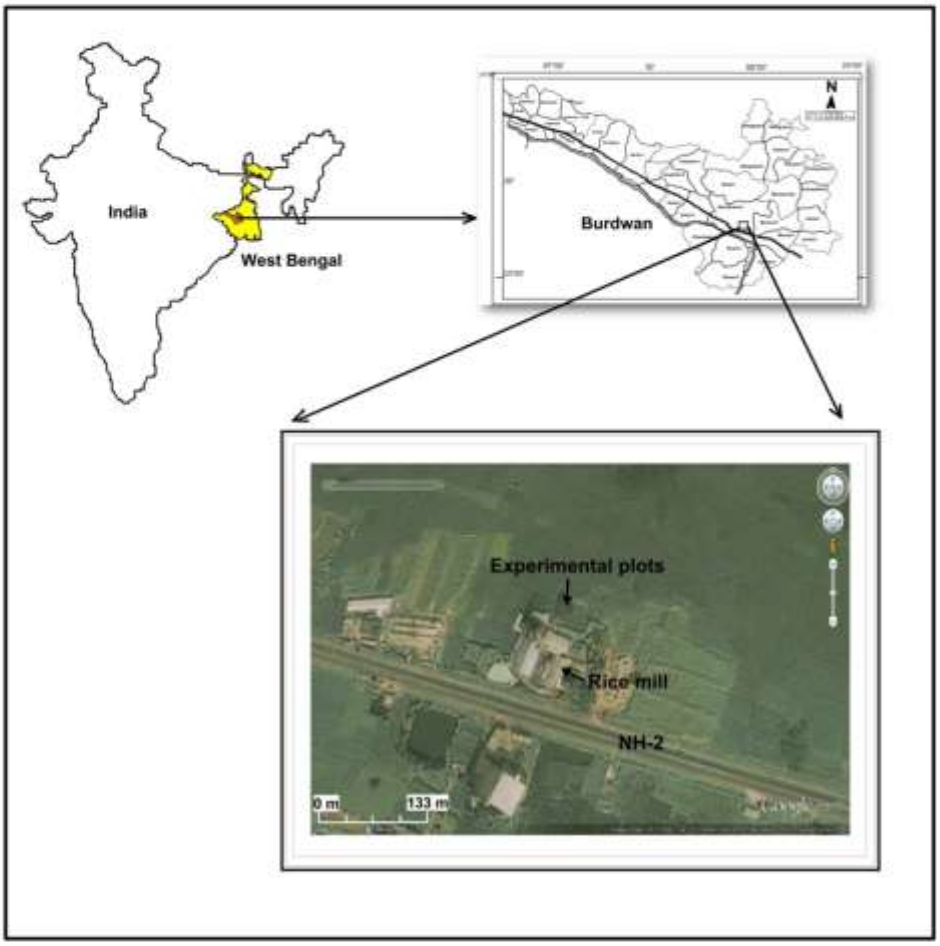

Figure 1: Study area location

MATERIALS AND METHODS

Effluent sample collections and analysis: The effluent samples were collected at regular interval from the industry discharge point throughout the winter. Altogether 03 samples were collected in wide-mouth 1 L acid washed plastic container previously raised with same sampling water. The pH, temperature, EC, DO was measured immediately after collection following standard method APHA 1998. Other parameters *viz.*, BOD, COD, TDS, TSS, Total hardness, Total Alkalinity, Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+}, K^{+}, PO_4^{3-}, SO_4^{2-}, NO_3^- Cl^-, CO_3^{2-} and HCO_3^- were measured by standard methods (APHA 1998). Fluoride (F^-) was analysed by ion-selective electrode (Orion).

Collection and analysis of rice husk ash: Rice husk ash was collected from the out let of Mechanical Dust Collector (MDC) machine of the said Rice Mill. Samples were immediately kept in air tight plastic bags and despatched for laboratory for further analysis. Samples were air dried and passed through 2 mm sieve. Physico-chemical analysis *i.e.* pH, EC (Muhr et al.1965), bulk density, water holding capacity (Black, 1965), organic

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carbon (Walkley and Black, 1934), available N (Subbiah and Asija 1956), P (Olsen et.al. 1954) and K (Ammonium acetate extraction) were measured.

Experimental design: The field experiments were conducted in a Randomized Block Design (RBD) system (Fig. 2) for four years (2007- 2010). Kufri Jyoti potato (*Solanum tuberosum*) variety was selected for this experiment. Details of treatments are represented in Table 1. First two years experiments were mainly focused to screen out the best doses of both effluent and rice husk ash. In the third year reduced dose (i.e. 20%, 30%, 40%, 50% reduction) of potassium based chemical fertilizers was applied along with screened out best dose of rice ash husk and effluent from the previous two years. A control experiment (T5) was also run in a parallel manner with the application of conventional dose of chemical fertilizer (i.e. N: P: K = 200:150:150) along with groundwater as irrigation water. Altogether there were three replicates and five treatments for this 3rd year experiment. For each year all the sub plot of all the replicates was of $15m^2$ in area.

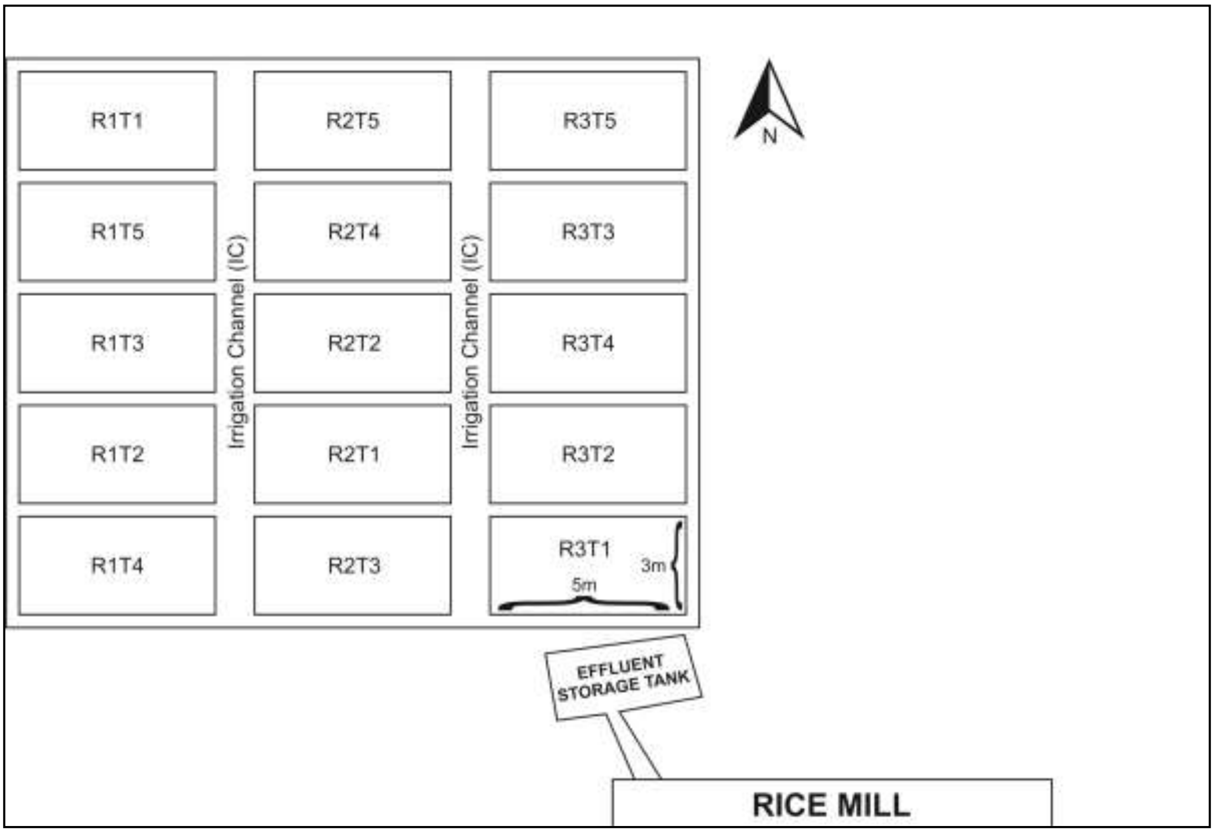

Figure 2: Randomized block design layout of experimental field

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Table 1: Details of treatments applied in the four years of experiment

Treatments in 2007					
Treatment	Rice husk ash/ha	N	P	K	Irrigation
T1(control)	Not applied	0.3 kg	0.225 kg	0.225kg	Groundwater
T2	300 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	Groundwater
T3	400 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	Groundwater
T4	500 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	Groundwater
T5	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	Groundwater
Treatments in 2008					
Treatment	Rice husk ash/ha	N	P	K	Irrigation
T1(control)	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	Groundwater
T2	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	10% effluent + 90% water
T3	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	25% effluent + 75% water
T4	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	50% effluent + 50% water
T5	600 kg rice husk ash	0.3 kg	0.225 kg	0.225kg	100% effluent
Treatments in 2009					
Treatment	Rice husk ash/ha	N	P	K	Irrigation
T1	600 kg husk ash	0.3 kg	0.225 kg	0.180 kg (20% reduction)	100% effluent
T2	600 kg husk ash	0.3 kg	0.225 kg	0.160 kg (30% reduction)	100% effluent
T3	600 kg husk ash	0.3 kg	0.225 kg	0.135 kg (40% reduction)	100% effluent
T4	600 kg husk ash	0.3 kg	0.225 kg	0.112 kg (50% reduction)	100% effluent
T5(control)	600 kg husk ash	0.3 kg	0.225 kg	0.225 kg(no reduction)	Groundwater

Potato tuber sampling and analysis: Tuber of 2″diameter was accepted for sampling. Tubers were cleaned with soft brush and kept in cold and dry place and analysis were done within a few days after harvesting. Biochemical analysis of tuber such as total soluble sugar, protein, ascorbic acid and crude fibre were estimated by the method of McCredie et.al. (1950), Lowry et.al.(1951), Mukherjee and Chowdhuri (1983) and Maynard (Ed) (1970) respectively.

Quality control assurance for biochemical analysis: All the chemical and reagents are analytical grades. Sulfuric acid (H_2SO_4), hydrochloric acid (HCl), sodium hydroxide (NaOH) and all biochemical reagents used for biochemical analysis were purchased from Merk (Darmstadt, Germany). TISAB III (Total Ionic Strengh Adjustment Buffer) concentrates with CDTA were purchased from Thermo Fisher Scientific, USA. All the glassware were kept overnight in 5 M HNO_3, rinsed with deionized water before used.

Statistical analysis

Pearson correlations: Correlation is a statistical technique that shows how strongly pairs of variables are related, and to determine the extent of changes in the value of an attribute are associated with changes in another attribute. The Pearson correlation among yield and other biochemical parameters of tubers and physic-chemical parameters was calculated by using the following formula:

$$r = \frac{\sum_{i-1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)s_X s_Y} \qquad \text{.....................(1)}$$

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Where, X and Y are two variables, with means $\overline{X}$ and $\overline{Y}$ respectively, and standard deviations of S_X and S_Y. The correlation coefficient *r* is a measure of the linear relationship between two attributes or columns of data. The value of *r* can range from -1 to +1 and is independent of the units of measurement. A value of *r* near 0 indicates little correlation between attributes; a value near +1 or -1 indicates a high level of correlation.

Analysis of variance (ANOVA): To analyze the tabulated data as observed in field experiment and laboratory analysis in different aspects Cocharn and Cox (1959), Fisher(1960), Panse and Sukhatme (1967), Gomez and Gomez (1984) were consulted. For interpreting the effect of different treatments under different cases, for comparison of F-value at 5% level of significance, Fisher and Yates (1953) table was followed.

RESULTS AND DISCUSSION

Irrigation water suitability of rice mill effluent: Physico-chemical analysis of effluent is represented in Table 2. Effluent has yellow in colour, very low DO content (<1 mg/L), and mean BOD and COD level of 450 mg/L and 630 mg/L respectively. The pH value of all the effluent samples are found to vary from 5.2 to 7.0 with an average of 6.4 and hence these effluents are found to be suitable for irrigation (recommended normal range of pH for irrigation water is 6.5 to 8.5). Average total hardness of the effluent samples is 1584.5 and 1625 mg/L during experiment respectively, which indicates the water as highly hard (Raghunath, 1987). The sodium hazard is expressed in terms of classification of irrigation water as low (SI<10), medium (S2: 10 to 18), high (S3: 18 to 26) and very high (S4>26). In studied effluent samples SAR value ranges from 2.98 to 3.42 with a mean of 3.13 during experiment. So effluent can be used for irrigation on almost all soils. According to US department of Agriculture (Wilcox 1955) all the effluent samples fall in the category of low-sodium and moderate salinity zone (Fig. 3). Magnesium ratio of more than 50% would adversely affect crop yield as the soils become more alkaline. The studied effluent samples have magnesium hazard less than 50 and that varies from 39.07 to 43.55. So these effluents are found to be suitable for irrigation. Chloride ion concentration also deserves due consideration, as according to Ayers and Branson (1975), when mg/L value of chloride in irrigation water is less than 4 is non-restricted, 4 to 10 moderately restricted and above 10 severely restricted for irrigation. In the tested samples of effluents chloride ranges from 5.3 to 9.4 mg/L with a mean value of 7.4 mg/L which indicates its suitability for irrigation. Wilcox (1955) recommended 1 mg/L maximum concentrations of fluoride in irrigation waters. Fluoride concentration of the collected samples varies between 0.59 to 0.71 mg/L with mean values of 0.66 mg/L. With respect to sulphate (mean 13.05 mg/L), iron (8.25 mg/L) and nitrate (9.66 mg/L) the rice mill effluent are well within the tolerance limit for irrigation purpose (Table 2). One of the major advantages of the effluent is the presence of elevated concentration of potassium (290 – 303 mg/L) and phosphate (378 – 392 mg/L) which may use as a substitute for potassium and phosphate based chemical fertilizer in potato cultivation.

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Parameters	Range	Mean ± SD	ISI limit for discharge of industrial effluent	
			On land for irrigation (ISI , 1977)	Into inland surface waters (ISI, 1974)
Colour		Yellow	-	-
Odour		Unpleasant	-	-
Temperature (°C)		25±5	-	40
pH	5.2-7	6.23±0.93	5.5-9.0	5.5-9
Conductivity (m mho/cm)	598-640	616±21.39	-	-
TDS (mg/L)	432.5-576.0	530.0±53.00	2100	2100
Dissolved oxygen(mg/L)	0.2-1.6	0.9±0.52	-	-
BOD at 20 °C (mg/L)	312.1-540.1	450.0±76. 61	100	30
COD (mg/L)	400.2-892.1	630.0±183.03	-	-
Total Alkalinity (mg/L)	180.7-340.1	272.0±58.	-	-
Total Hardness (mg/L)	1584.5-1625	1610.17±22.32	-	-
Na^+ (mg/L)	12-13.8	12.60±1.04	-	-
K^+ (mg/L)	292-303	297.00±5.57	-	-
Ca^{2+} (mg/L)	18.3-19.8	18.90±0.79	-	-
Mg^{2+} (mg/L)	12.7-14.12	13.30±0.73	-	-
Fe (mg/L)	7.32-8.74	8.25±0.81	-	-
Chloride (mg/L)	5.3-9.4	7.40±2.05	600	1000
Sulphate (mg/L)	12.65-13.6	13.05±0.49	1000	1000
Phosphate (mg/L)	378-392	385.33±7.02	-	-
Nitrate (mg/L)	8.01-11	9.67±3.22	-	-
Fluoride (mg/L)	0.67-0.71	0.66±0.06		

Table 2: Physico-chemical characteristics of the effluent of a rice mill

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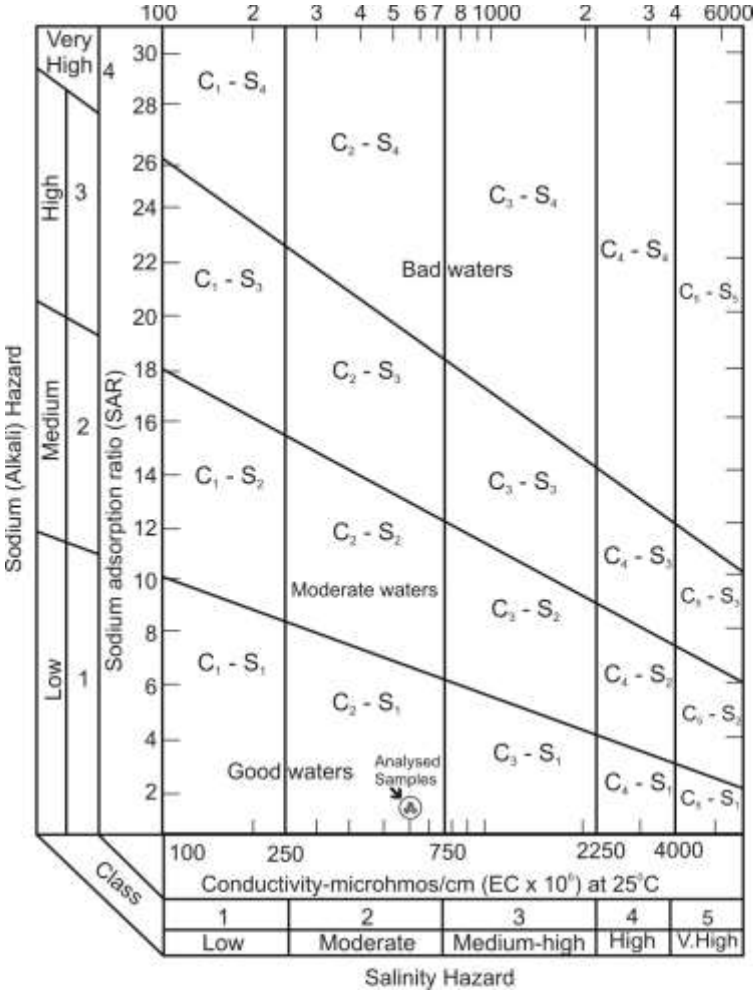

Figure 3: USSLS (Wilcox, 1955) classification of irrigation water

Nutritive status of rice husk ash: Rice husk ash is the residue produced from the combustion of rice husk in the furnace consisting of mineral constituents which is not fully burnt. Experimental rice husk ash samples are alkaline in nature (7.5 - 8.8) and have moderate EC (0.0063 - 0.0064 dS/cm). In comparison to bituminous coal fly ash samples (50 - 60% porosity; Basu et al. 2008) rice husk ash has higher porosity (62 - 70%) and low bulk density of < 1 g/cc. But it has slightly lesser water holding capacity (28 - 35%) in comparison to bituminous coal fly ash (35 - 40%). As per as the macronutrient status is concerned the rice husk ash contains significant amount of organic carbon (2.5 - 3.2%) and very low nitrogen (mean 0.56 mg/L) and high potassium (mean 180 kg/ha) and phosphate (194 kg/ha). Pande et al. 2009 reported that potassium and phosphate content in the fly ash of other industries are 0.15 – 3.5 mg/L and 0.004 – 0.8% respectively. So presence of high amount of porosity and organic carbon will make a better soil health for potato cultivation.

Effect of rice mill wastes on biochemical constituents of potato tubers

Sugar: Sugar is the most important factor when the quality of potato is under judgment. As potato contains potential amount of sugar within so it is considered to be third most important source of carbohydrate after rice and wheat around the globe. The sugar content of potatoes is very low at an average of 0.5% of the wet weight or just over 2% of dry weight. However, sugar content is highly variable, depending on the type, maturity and physiological state of the potato.

In 2007 sugar content in control replicate (T1) is 1.36 gm/100 gm where as in T5 the concentration is 2.56 gm/100 gm (88% increases). Here noticeable that T5 is very much nearer to the obtained highest value (T2) *i.e.* 3.26 gm/100 gm (139%). In the year 2008 (T1) control show sugar content of 1.93 gm/100 gm and T5 shows sugar content 2.31 gm/100 gm (19%). This is the highest sugar content found this year. In the year 2009 mean sugar

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content in control replicate (T5) is 1.83 gm/100 gm. Among the treated replicates T3 shows the highest sugar content (2.09 gm/100 gm) among all other treatments as well as 14% increase with respect to control.

Potassium deficiency changes carbohydrate metabolism, with negative consequences such as accumulation of soluble carbohydrates and in decrease in starch content (Mengel and Kirkby, 1987). Accumulation of reducing sugars and decrease of starch in potato tubers are the cause of undesired dark-colored potato chips which occur under low K nutrition levels (Martin-Prevel, 1989; Perrenoud, 1983; Usherwood, 1985). The significant increase in sugar content with the best dose of treatment and tuber yield indicates that there is no deficiency of K-fertilization.

Sugar content shows a significant positive correlation with crude fiber and yield in all the experimental years, but significant correlation with yield (r=0.500) is found in 2009 except crude fiber (r=0.258). ANOVA results suggest that there is a significant mean difference (LSD 5%) between best yield treatment (T5) and control (T1) in 2007, 2008 and 2009.

Protein: Tuber contains about 2% protein on a fresh weight basis (FW) or about 10% on a dry weight (DW) basis. On a DW basis, potato protein content is comparable to that of wheat and higher than most rice or corn cultivars, but on an FW basis it is much lower than that of some other crops, such as soybean.

During 1st year of experiment the mean protein content in control replicate (T1) is 157.33 mg/100gm, whereas T5 shows highest protein content (143.55 mg/100gm) among the replicates. In the 2nd i.e. 2008, (T1) control shows protein content is 138.31 mg/100 gm and among the treatment T5 shows the highest mean protein content of 169.62 mg/100gm. In the year 2009, control replicate (T5) achieved mean protein content of 171.72 mg/100gm, whereas, treated replicate (T3) shows highest protein content (176.04 mg/100gm).

Pearson correlation co-efficient reveals that protein content has a significant positive (r=0.552) correlation with yield. ANOVA results suggest that there is a significant mean difference (LSD 5%) between best yield treatment (T5) and (T3) with control (T1) in 2008 and 2009 respectively.

Ascorbic acid: Ascorbic acid (vitamin C) is the main vitamin in potatoes. Global dietary contribution of vitamin C from potatoes is important with an estimate of 40% of daily-recommended intake (OECD 2002). There is a wide range of vitamin C content in tubers, with the usual range for freshly harvested tubers reported as 10–25 mg/100 g FW.

In 2007 and 2008 mean ascorbic acid content in control replicate (T1) are 17.04 mg/100gm and 20.08 mg/100gm, whereas among treatment replicates, T5 shows maximum ascorbic acid content of 20.22 mg/100gm and 25.06 mg/100gm in each year respectively. Experiment at 2009 shows the significant increment in ascorbic acid content in T3 treatment replicate (176.04 mg/100gm) in comparison to control replicate (T5).

This increase in ascorbic acid content may be attributed to the additional source of K input to the soil through effluent and rice husk ash. High concentrations of K usually lead to an increase in organic acid concentration, also having a beneficial effect on ascorbic acid levels (Bergmann, 1992). Some other experiments also show an increase of vitamin C and in the tubers (Nowacki et al. 2000). In 2009 ascorbic acid has a significant positive correlation with dry matter (r=0.435) and yield (r=0.465) of tubers. ANOVA results suggest that there is a significant mean difference (LSD 5%) between best yield treatment and control in 2007, 2008 and 2009.

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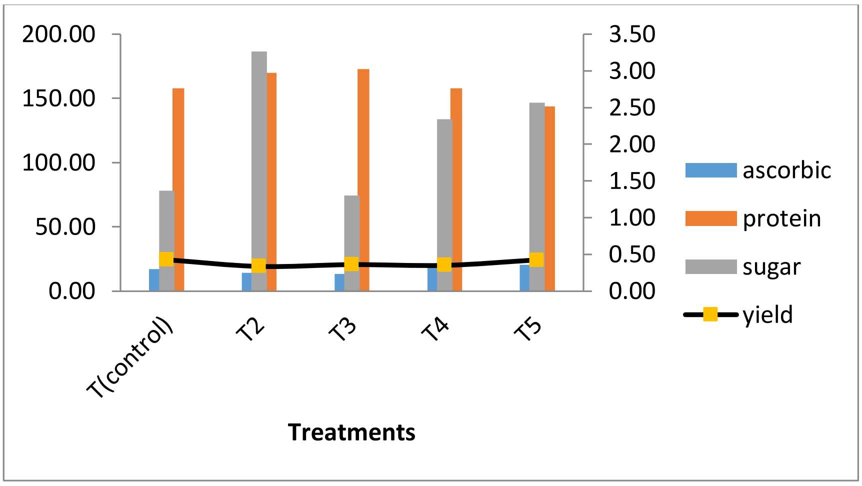

Figure 4: Status of biochemical constituents along with yield in potato tubers (in 2007)

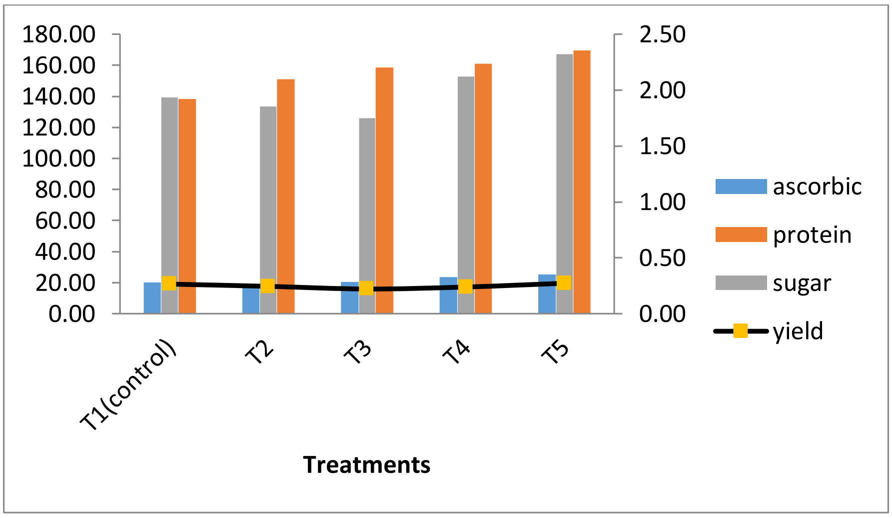

Figure 5: Status of biochemical constituents along with yield in potato tubers (in 2008)

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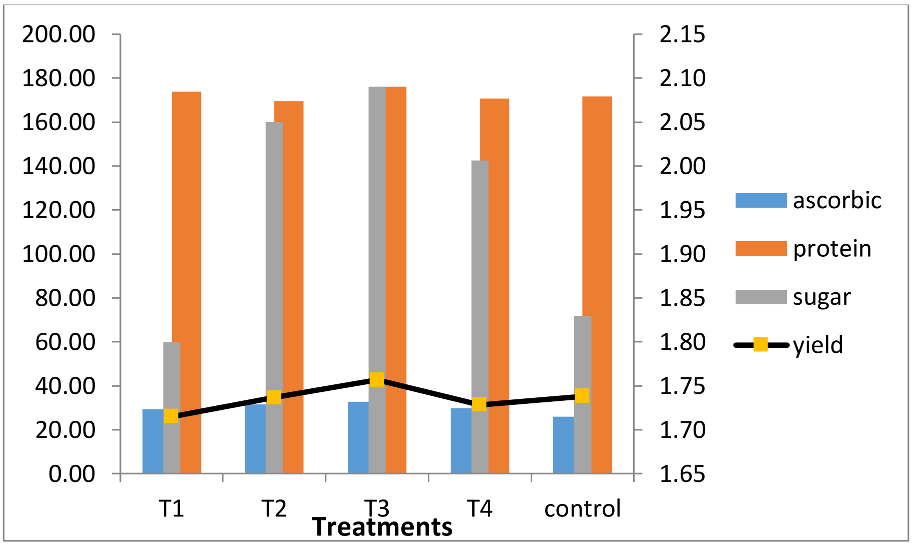

Figure 6: Status of biochemical constituents along with yield in potato tubers (in 2009)

Effect of rice mill wastes on crude fiber and yield of tubers

Crude fiber (Dietary fiber): Dietary fibre consists mainly of the polysaccharides of plant cell walls. The dietary fibre may "dilute" highly caloric components in food, stimulate peristaltic movement and retard digestion of some other food components. Potatoes contain a relatively small proportion of dietary fibre because they are a storage organ in which starch becomes the dominant constituent in the mature tuber. Most potatoes contain about 1-3% dietary fibre compared with about 17% starch, on an edible weight basis.

During experimental year 2007, the control replicate (T1) shows 0.63% crude fiber content and the treatment T5 replicate shows the highest crude fiber content and *i.e.*, 0.71%. Other replicates like T2, T3, and T4 show crude fiber content of 0.60%, 0.62%, 0.65% respectively. In the year 2008, crude fiber content in the control replicate (T1) is 0.60% whereas, in treatment replicate (T5) it is 0.67%, which is highest obtained value in this year. In the year 2009, control replicate shows mean value of 0.56% crude fiber content. Among treatment replicates T3 yields highest crude fiber content (0.69%).

***Yield*:** Potato is a crop of cold climatic condition, that's why it is mainly cultivated in the high altitude lands (hills) and in plain land. As it is cultivated in different land forms and in different seasons it shows extensive variability in productivity in different provinces. In the present experiment significant variability of yield has noticed which is mentioned as follows.

In the year 2007, the control replicate (T1) shows yield of 24.16 ton/ha and among the treatments T5 shows mean yield of 24.06 ton/ha. This value is not higher than that of control replicate but highest within all other treatment replicates. In the year 2008, the obtained mean yield from the control replicate (T1) is 19.16 ton/ha whereas in treatment replicate (T5) it is 19.7 ton/ha. This is the highest obtained yield this year. In the final year of experiment control replicate shows a yield of 35.1 ton/ha and among the treatment replicates T3 shows highest yield of 42.6 ton/ha. So application of reduced dose of potash based chemical fertilizer (40% reduction) along with the application of 100% rice mill effluents and 600kg rice husk ash gives rise to 21% increase in production of potato.

CONCLUSION

Present study reveals that 40% reduction of potash based chemical fertilizer give rise to the best yield and quality parameters of tubers. So, the farmers will be benefited in both the way as they will achieve higher production with better quality as well as reduction of cultivation cost. In other respect reuse of this effluent and rice husk ash will greatly reduce the pollutant load in the environment as well as conserve groundwater resource. Rice mill waste also contain significant quantity of phosphate, so further research will also help to reduce the application of phosphate fertilizer and hence the benefit mentioned above will be achieved with higher degree.

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