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# The Effect of Straw, Stubble and Potassium on Grain Yield of Rice in Rice-Rice Cropping Systems in the Mid-Country Wet Zone of Sri Lanka

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**ABSTRACT:** Rice straw is rich in potassium (K). Application of rice straw is encouraged to recycle K in rice soils. In this aspect the importance of rice stubble for increasing soil fertility has not been given due attention. Most of the rice farmers have a multitude of uses of rice straw and hence are reluctant to return straw to the rice fields. Thus, despite extensive and expensive promotions, many rice farmers continue to remove straw and apply K nutrient to their rice crop. Therefore, this study was conducted with the objective of investigating the yield and economic benefits of addition of straw and K fertilizers in the presence of stubble of the preceding rice crop in rice-rice cropping systems in the mid-country wet zone of Sri Lanka.

Six straw-stubble-potassium combinations and the farmers' practice were tested in parallel experiments with two common rice age groups (viz. 90- and 105-day), in a randomised complete block design with three replicates during 1996-1997 in the district of Kandy, Sri Lanka. Grain yield and its components, straw and stubble dry weight, harvest index, gross and net income were assessed. The farmers' practice of applying half the recommended rate of K (8.5 kg K/ha) 7-14 days before flowering in the presence of the stubble of the preceding rice crop gave the highest grain yields of 3.82 and 4.78 t $ha^{-1}$ for 90-day and 105 day rice varieties, respectively. These yields were significantly greater than that of the control treatment that received rice straw and stubble only, but not significantly different from the treatment receiving both straw and 17 kg K/ha in the presence of stubble. The application of K fertilizer showed increases in the number of filled grains per panicle (significant in 90 –day rice only) and grain weight (not significant), which collectively increased grain yield and net income compared to control. The farmers' practice of using half the recommended dose of K (8.5 kg/ha) prior to flowering offered higher yields and net returns compared to the control treatment having straw returned to the rice field in the presence of stubble of the preceding rice crop.

**KEYWORDS:** Rice stubble, rice straw, potassium, rice grain yield, harvest index, double cropping.

## INTRODUCTION

Rice occupies approximately 33 percent of the total cultivated area in Sri Lanka, which accounts for 0.65 million hectares. Fifty five percent of the rice area is in the dry zone, while 20% and 25% are found in the intermediate and wet zones, respectively. Rice production has become a marginal entity at present due to increased costs of inputs, especially labor, fertilizers and pesticides and low farm gate price. Benefits from using high yielding varieties with high responsiveness to fertilizers could not be accrued due to the high costs of the fertilizers. There has been a decline in rice yields during the last two decades, and rice imports have compensated the demand.

The addition of rice straw is a recommended practice for maintaining soil fertility[1]. Rice straw contains a large amount of nutrients: a ton of rice straw adds 6.16 kg of nitrogen (N), 0.83 kg of phosphorus (P), 22.5 kg of potassium (K), 4.16 kg of calcium (Ca), 2.33 kg of magnesium (Mg), and 0.83 kg of sulphur (S) according to Nagarajah[2]. These values confirm the importance of straw incorporation as a mean to return such nutrients in order to reduce the cost of fertilizers[2,3,4]. Due to high K content in straw, returning straw to the rice field was emphasized[1]. Tanaka[5] and Ponnamperuma[4] observed yield increases with straw application.

Due to multitude uses of straw, i.e. mulching material for moisture conservation in upland crops, in home gardens and seed beds; roofing material, cattle feed when enriched with urea, etc. only a very small percentage of farmers leave straw in the rice field; In some situations farmers burn straw to avoid its interference with mechanization during land preparation. These reasons have hampered recycling rice straw in rice production systems.

Return of straw is recommended in order to reduce cost of fertilization, in particular, of K, and associated cost of production. In rice soils, soil structure has a little role to play, since puddling which destroys the structure is adopted to create the hardpan to retain water. If organic matter is required, the root mass left at harvest would be able to satisfy the soil organic matter requirement. On the other hand, soils of the upcountry wet zone of Sri Lanka are considered to be high in K. As a result, a low crop response to applied K is seen[6], and therefore, K has been removed from the basic rice fertilizers and top dressing mixtures[1]. This is on the assumption that the K level in soils would be adequate to satisfy the K needs of rice crop. Potassium is a major nutrient with a critical role in regulating assimilates transportation, so its short supply could affect the productivity of rice[7]. The removal of K from fertilizer mixtures would lead to a greater risk in rice production, unless yearly estimation of K contents in rice soils is adopted. The removal of K from both basic and top dressing fertilizer mixtures, promotion of straw recycling to return K removed by the rice crop and trust in the high soil K content in rice soils are logically related to each other. However, the farmers continue to remove straw and fertilize the rice crop with K before seeding and flowering stages. This practice ensures that rice yields do not suffer due to K nutrition. Otherwise, the farmers would not adopt such practices and risk their own crop and economy. There has been no information so far available to convince the farmers of the relative benefits of potential rice straw and potassium fertilizer interaction.

The objective of this study was to determine the effects of straw application and potassium fertilization on rice yield and net return in the rice-rice cropping systems in the mid-country wet zone of Sri Lanka.

## Materials and Methods

This study was conducted in a farmer field in Medawala, at an elevation 480 m AMSL in the district of Kandy, Sri Lanka from November, 1996 to mid March, 1997. The experiment site was situated in a continuous rice producing area where two rice crops are usually grown in the mid-country wet zone. The soils in the experimental site are sandy clay loam with 38% sand, 15% clay and 47% silt, and well-drained. At the commencement of the study, the soil pH was 5.9, and the soil contained 0.18% total N, 0.43% exchangeable K, 8.7 mg/kg available P, and C 3.2% organic.

This study consisted of two experiments, conducted in parallel using rice varieties from two age groups, [viz. BG 34-8 (90 days) and BG 34-6 (105 days)]. Seven experimental treatments composed of selected combinations of rice straw application, rice stubble (root mass and remaining shoot portion of the previous rice crop) management and potassium application (Table 1) were tested, along with the farmers' practice, for two rice varieties. Treatments were arranged in a randomised complete block design with three replicates.

The research site was identified prior to harvesting the preceding crop of rice, and the required area was estimated and demarcated. At harvesting of preceding crop of rice, five 1 $m^2$ samples were collected from the crop by manually harvesting the plants at approximately 15 cm above the ground level, the grains and straw were separated, and the dry weight of straw was recorded after drying it first in the sun and then in an oven for about 5 days. This information was used to quantify the weight of straw to be incorporated into the plots in the succeeding study.

After harvesting the preceding rice crop, the field was fenced, and field bunds (dykes) were prepared (plot size was 3m x 3m) to differentiate the plots and for convenient crop and water management. Straw application, stubble managemthe ent and K fertilizer application were adopted as shown in the treatments (Table 1). Treatments with codes starting with "0" received no straw and hence even remaining straw at the harvest of previous crop was removed, while codes that begin with "1" had sun dried and stored straw applied and incorporated at the rate of 2.5 t/ha. Similarly, for treatments having "0" in the middle of the code, plant stubble was uprooted and removed from the plot by hand pulling after impounding water during the first ploughing (manually adopted due to different needs of soil management). Rice stubble was left and mixed up with the soils during first ploughing when the code for stubble management was "1". For K management, treatments had the respective code of "0" received no K fertilizer, while treatments with the code "1" received 17 kg/ha of K using muriate of potash (50% K) at the basal dressing, except the farmers' practice. The farmers' practice (01F) was such that no straw was added and no N applied at basal dressing. However, P was given at the rate of 12 kg/ha at basal dressing. As top dressing, 28.75 kg/ha of N was applied at 3 weeks after seeding (WAS), and both N and K were applied at the rate of 15 and 8.5 kg/ha at 7 WAS for 90-day rice, and at 8 WAS for 105-day rice.

Land preparation for the experiments was commenced in early October with the onset of inter-monsoon rains. The land was ploughed twice at a one-week interval, harrowed twice at a one-week interval, and the second harrowing was combined with puddling and levelling prior to establishment of rice. After each land preparation operation, plots were impounded with water to about 4 inches above the soil clods to kill all weeds. All operations were done manually. All plots, except plots in the farmers' practice, were given a basal dressing of nitrogen (N) and phosphorus (P) at the rates of 15 and 12 kg/ha in the form of urea (46% N) and concentrated super phosphate (19.8% P) prior to levelling. Pre-germinated rice seeds were broadcasted at the rate of 105 kg/ha in both experiments. N was top dressed for 90-day rice at the rate of 15 and 30 kg/ha at 3 and 7 WAS respectively, and at 3 and 8 WAS respectively, for 105-day rice. Potassium was applied as per treatments only.

Crop management was done uniformly across all treatments in both experiments. The crop was examined frequently for pest and diseases. Weeds were controlled by hand-pulling and by water management. Management of insect pests was done based on estimation of pest populations. Carbofuran was applied to avoid insect pest damage. These practices were adopted for both experiments. The 90-day rice crop matured in 114 days, while 105-day rice reached maturity in 124 days, as is usually observed due to cool temperatures in the mid country wet zone. Harvesting was done on March 3 of the 90-day crop while 105-day rice was harvested on March 13 1997.

The observations included yield parameters, which were taken from a randomly selected sample area of one square meter grid from each plot. Using this sample, mean tiller and panicle number per plant, number of filled and unfilled grains per panicle, 100-grain weight, and straw and stubble yields were determined. In the determination of stubble and straw, all rice plants in a 1 $m^2$ sample area were uprooted, washed well to remove soil particles, straw and stubble were separated, sun-dried first and after which oven-dried until a constant weight was reached and then the dry weight was recorded. For the final grain yield, the crop was harvested from 3 $m^2$ area, i.e. after removing the 0.5 m section around the plot as a border area. Plants were manually harvested at normal height, around 15 cm above the ground level. Grains were sun dried after threshing and cleaning, and total grain weight was recorded in each plot. A sub sample of one kg each was then taken from each of the plot and oven dried until a constant weight was reached, and the grain dry weight was recorded. Based on these values, the bulk harvest in each plot was converted to the grain weight at 14% to determine the final grain yield. Using the yield and total biomass (straw + stubble) the harvest index was computed[8]. Net returns were computed after considering the total cost incurred on application of straw and fertilizers, pest management, weeding, etc, except the land value, and the gross income using the farm-gate price in LKRs. 9.50 per kg of raw (non-milled) paddy [US $1 = 97 LKRs]. The cost involved with the removal of stubble, as well as addition of straw, was recorded, but not added to the total cost, since some farmers thresh harvested rice crop in the same field, thus leaving straw in the same field. The straw is later removed for feeding cattle and also to use as mulching material for upland crops. Therefore these values were not used in the gross and net income calculations.

**Table 1.** Experimental treatments.

| Treatment Code | Factor | | | | | |
|---|---|---|---|---|---|---|
| | Straw | | Stubble | | Potassium*** | |
| 110* | Added | (1) | Present | (1) | Not applied | (0) |
| 111 | Added | (1) | Present | (1) | 17 kg/ha | (1) |
| 010 | Removed | (0) | Present | (1) | Not applied | (0) |
| 011 | Removed | (0) | Present | (1) | 17 kg/ha | (1) |
| 001 | Removed | (0) | Removed | (0) | 17 kg/ha | (1) |
| 000 | Removed | (0) | Removed | (0) | Not applied | (0) |
| 01F** | Removed | (0) | Present | (1) | 8.5 kg/ha | (F) |

* Department of Agriculture recommendation (control).
** Farmers' practice – straw removed and half the recommended dose of K (8.5 kg/ha) applied for 90 and 105 day rice, at 7 and 8 weeks after seeding (WAS), respectively.
*** K was added only at the basal dressing and no K was applied as top dressing, except in the farmers' practice.

The analysis of variance was performed for the experimental data and means were separated with the Fisher's protected LSD[9].

## Results and Discussion

### Grain Yield and Yield Components

Plant density at harvest, tiller number and panicle number per plant and 100-grain weight were not significantly different among treatments (Tables 1 and 2). Plant density ranged from 65 to 90 plants $m^{-2}$ in the 90-day rice variety and from 74 to 85 plants in the 105-day variety. Mean tiller number per plant ranged from 2.7 to 3.7 in the 90-day rice variety and in the 105-day variety from 3.0 to 4.3. The mean panicle number per plant ranged from 1.9 to 2.6 in the 90-day rice variety and from 2.3 to 2.8 in the 105-day variety. The mean weight of 100-grains in 90-day rice varied from 2.37 g in the treatment receiving straw and stubble without K (code 110 – Department of Agriculture recommended practice) to 2.60 g in both farmers' practice (code 01F) and the treatment receiving all straw, stubble and K (code 111) (Table 2). In 105-day rice, 100-grain mean weight ranged from 2.58 g in the treatment that received neither straw, stubble nor K fertilizer, to 2.93 g in the farmers' practice (Table 3).

The number of filled grains per panicle was significantly different among treatments for both rice varieties (Table 3). The farmers' practice (code 01F) had the highest number of filled grains per panicle in

**Table 2.** Plant density and mean tiller and panicle number per plant of rice as influenced by the incorporation of straw, stubble and K.

| Treatment | Plant density (no. of plants $m^{-2}$) | | Mean tillers (no. $plant^{-1}$) | | Panicles (no. $plant^{-1}$) | |
|---|---|---|---|---|---|---|
| | 90-day rice | 105-day rice | 90-day rice | 105-day rice | 90-day rice | 105-day rice |
| 110* | 67 ± 15 | 79 ± 5 | 3.0 ± 0.0 | 3.0 ± 1.0 | 2.4 ± 0.3 | 2.4 ± 0.5 |
| 111 | 76 ± 16 | 85 ± 8 | 3.0 ± 0.0 | 3.0 ± 0.0 | 2.4 ± 0.4 | 2.3 ± 0.1 |
| 010 | 90 ± 7 | 79 ± 10 | 3.0 ± 1.0 | 4.3 ± 1.5 | 1.9 ± 0.3 | 2.8 ± 0.3 |
| 011 | 83 ± 9 | 78 ± 8 | 2.7 ± 0.6 | 3.3 ± 0.6 | 2.0 ± 0.2 | 2.6 ± 0.3 |
| 001 | 78 ± 5 | 75 ± 15 | 3.7 ± 0.6 | 3.0 ± 1.0 | 2.3 ± 0.5 | 2.4 ± 0.3 |
| 000 | 65 ± 19 | 74 ± 12 | 3.0 ± 0.0 | 3.0 ± 0.0 | 2.6 ± 0.2 | 2.3 ± 0.1 |
| 01F** | 76 ± 11 | 84 ± 4 | 2.7 ± 0.6 | 3.3 ± 0.6 | 2.2 ± 0.5 | 2.7 ± 0.4 |
| Lsd*** | ns | ns | Ns | ns | ns | ns |
| CV% | 13.68 | 10.33 | 16.26 | 26.56 | 15.32 | 10.57 |

* Department of Agriculture Recommendation (Control).
** Farmers' practice, in which straw removed and half the recommended dose of K (8.5 kg/ha) applied for 90 and 105 day rice, at 7 and 8 weeks after seeding (WAS), respectively.
*** ns = treatment means are not significantly different at p=0.05.

both varieties: 90 grains (84%) in 90-day rice and 83 grains (78%) in 105-day rice. In addition in 105-day rice, the highest number of filled grains was also observed in treatments that received no straw, but both stubble and K, which was similar to the farmers' practice, except for receiving different K levels and different timing of basic fertilization. In both age groups, plots receiving K near grain filling had a higher number of filled grains when compared to corresponding treatments which received no K. The lowest number of filled grains was in the plots where all three factors were absent. This shows that treatments with codes 000 and 001 had no residual pools of nutrients from the previous crop and hence the crop was vulnerable for nutrient limitations. The plots treated with straw and stubble but no K (i.e. Department of Agriculture recommended practice) gave a mean number of filled grains of 64 per panicle (80%), which was significantly lower than both farmers' practice and those plots that received straw, stubble and K (83 grains panicle).

Grain yield was significantly influenced by the treatments in both age groups of rice (Table 3). In 90-day rice, the highest yield was given by the farmers' practice (3.82 t $ha^{-1}$). Treatments that received both straw and stubble gave a 0.93 t/ha yield increase with the addition of K (p=0.05) (111) when compared to treatment 110 in 90-day rice and only 0.29 t/ha yield increase in treatment 111 over treatment 110 in 105-day rice with the addition of K. In the absence of straw only, K addition did show a significant yield increase of 1.10 t/ha (p=0.05) in the treatment 011 in 105-day rice compared to the treatment that received no K. Similarly, addition of K gave a non-significant yield increase in both 90- and 105-day rice when treatments 000 and 001 were compared. However, the yield increase in the farmers' practice (01F) was significantly greater than all treatments, except 111 and 011. Application of K before flowering was the specific difference in the farmers' practice when compared to treatments 111 and 011. This indicates the potential contribution by

**Table 3.** Mean number of filled grains, 100-grain weight and grain yield of rice as influenced by the incorporation of straw, stubble and K.

| Treatment | Filled grains*** (no. $panicle^{-1}$) | | Grain weight (g. per 100 $seeds^{-1}$) | | Grain Yield (t $ha^{-1}$) | |
|---|---|---|---|---|---|---|
| | 90-day rice | 105-day rice | 90-day rice | 105-day rice | 90-day rice | 105-day rice |
| 110* | 64 ± 8 (80) | 71 ± 4 (79) | 2.37 ± 0.21 | 2.70 ± 0.26 | 2.70 ± 0.21 | 3.87 ± 0.77 |
| 111 | 83 ± 13 (84) | 78 ± 10 (80) | 2.60 ± 0.26 | 2.90 ± 0.36 | 3.63 ± 0.20 | 4.16 ± 0.08 |
| 010 | 72 ±12 (77) | 59 ± 5 (75) | 2.58 ± 0.25 | 2.60 ± 0.17 | 3.05 ± 0.17 | 3.47 ± 0.27 |
| 011 | 78 ± 9 (80) | 83 ± 6 (89) | 2.57 ± 0.21 | 2.78 ± 0.14 | 3.34 ± 0.56 | 4.56 ± 0.32 |
| 001 | 58 ± 10 (72) | 66 ± 11 (83) | 2.53 ± 0.15 | 2.87 ± 0.40 | 2.60 ± 0.69 | 3.47 ± 0.50 |
| 000 | 52 ± 14 (68) | 62 ± 8 (83) | 2.52 ± 0.23 | 2.58 ± 0.26 | 2.27 ± 0.31 | 2.73 ± 0.19 |
| 01F** | 90 ± 7 (84) | 83 ± 7 (78) | 2.60 ± 0.10 | 2.93 ± 0.11 | 3.82 ± 0.30 | 4.78 ± 0.79 |
| LSD**** (p=0.05) | 18 | 16 | ns | ns | 0.67 | 0.77 |
| CV% | 14.16 | 12.23 | 7.46 | 8.89 | 12.38 | 10.99 |

* Department of Agriculture recommendation (Control).
** Farmers' practice, in which straw removed and half the recommended dose of K (8.5 kg/ha) applied for 90 and 105 day rice, at 7 and 8 weeks after seeding (WAS), respectively.
*** Values within parenthesis indicate the percentages of each grain type compared to total grains.
**** Probability level of significance: * significant at p=0.05, ns – not significant at p=0.05.

K fertilizers, and increased yield benefits in the application of K towards flowering instead of at the basal dressing storage, when the initial K needs are satisfied by decaying stubble. The results also showed a compensatory effect by the stubble of the preceding rice crop for the need of returning straw.

Grain yield in 105-day rice was higher than in 90-day rice. The highest grain yield (4.78 t $ha^{-1}$) was also recorded in the farmers' practice, and the lowest by the treatment denoted by 000 (2.73 t $ha^{-1}$). The behaviour of the grain yield among treatments was the same in the 90-day variety, except the treatment 01F out yielded treatment 111, but the differences were not significant.

In both age groups of rice, treatments receiving K had significantly higher grain yields than corresponding treatments receiving no K. On the other hand, at each level of K there was no significant difference in grain yield between treatments with and without straw. Similarly, in the presence of rice stubble there was no significant difference in grain yield with straw application. This confirms the importance of and valuable contribution by rice stubble to the succeeding rice crop, to which it provides nutrients as well as contributing to the regulation of soil conditions. Therefore, demand for using straw is negated by the plant stubble left in the form of root biomass of the preceding crop. For higher grain yield, there is a greater influence by the application of K than returning straw to the rice field. This is mainly to assist assimilate translocation in the presence of K, thereby ensuring higher grain yields [7].

## Production of Straw, Stubble, Total Residue and Harvest Index

Dry weight of straw was significantly influenced by the treatments in both 90- and 105-day rice varieties (Table 4). In 90-day rice, straw weight was significantly lower in treatments that had a limited supply of K, as well as organic matter in terms of either rice straw, or stubble or both when compared to the rest, including the farmers' practice. The farmers' practice had stubble, while treatments 110 and 111 had both straw and stubble dry weight. Decomposition of these residues may have provided nutrients to the succeeding crop after about 30 days, and looked after its nutrient requirement [10]. The plots that received neither straw nor stubble had a lower straw dry weight too, which could be attributed to nutrient limitations. Both basal and top dressing of N for every plot may have decreased the difference of dry matter production among treatments.

The dry weight of straw behaved similarly in 105-day rice too, except in that the complete treatment (111) gave an insignificantly higher straw yield than treatment 110 and the farmers' practice (01F). Straw weight ranged from 1.59 t $ha^{-1}$ in the treatment denoted by 000 to 2.94 t $ha^{-1}$ in the farmers' practice in 90-day rice with no significant difference between the complete treatment and the farmers' practice. A similar trend existed in 105-day rice and the straw dry matter ranged from 1.76 in the treatment 000 to 3.15 t $ha^{-1}$ in treatment 011.

The dry weight of stubble was also significantly influenced by the treatments. In both 90- and 105-day rice, stubble weight ranged from 2.43 t $ha^{-1}$ in the poor fertility level condition (Treatment 000) to 3.72 t $ha^{-1}$ in the farmers' practice (Treatment 01F). Weight of stubble was higher in treatments that received either straw or stubble or both and K. Conversely, the stubble weight was lower in treatments that had no residual components.

The total dry weight of the residue ranged from

**Table 4.** Dry weight of straw and stubble, total dry weight of residue and harvest index of rice as influenced by the presence of straw, stubble and K.

| Treatment | Dry weight of straw (t $ha^{-1}$) | | Dry weight of stubble (t $ha^{-1}$) | | Dry weight of total residue (t $ha^{-1}$) | | Harvest Index | |
|---|---|---|---|---|---|---|---|---|
| | 90-day rice | 105-day rice | 90-day rice | 105 day rice | 90-day rice | 105-day rice | 90-day rice | 105-day rice |
| 110* | 2.92±0.59 | 2.48±0.62 | 3.41±1.89 | 3.55±2.76 | 6.33±2.14 | 6.03±1.67 | 0.30±0.12 | 0.39±0.02 |
| 111 | 2.73±0.87 | 2.68±0.31 | 3.55±1.21 | 3.98±0.19 | 6.28±0.43 | 6.66±2.71 | 0.37±0.03 | 0.38±0.04 |
| 010 | 1.96±0.05 | 2.43±0.08 | 2.75±0.66 | 2.92±2.29 | 4.71±0.64 | 5.35±2.27 | 0.39±0.03 | 0.39±0.13 |
| 011 | 2.10±0.53 | 3.15±0.51 | 3.16±0.85 | 3.25±2.34 | 5.26±1.61 | 6.40±1.88 | 0.39±0.04 | 0.42±0.04 |
| 001 | 1.89±0.17 | 1.85±0.20 | 2.57±0.55 | 1.96±0.94 | 4.46±0.72 | 3.81±0.84 | 0.37±0.05 | 0.48±0.02 |
| 000 | 1.59±0.21 | 1.76±0.32 | 2.43±0.92 | 2.15±0.49 | 4.02±1.12 | 3.91±0.81 | 0.36±0.08 | 0.41±0.05 |
| 01F** | 2.94±1.02 | 2.63±0.23 | 3.72±0.57 | 3.48±1.58 | 6.66±0.53 | 6.11±0.43 | 0.36±0.01 | 0.45±0.02 |
| Lsd*** | 0.96 # | 0.65 # | 1.02**** | 1.23**** | 1.86 # | 2.19 # | ns | ns |
| CV% | 23.71 | 15.17 | 34.25 | 42.53 | 22.43 | 25.03 | 19.22 | 15.05 |

* Department of Agriculture recommendation (Control).
** Farmers' practice, in which straw removed and half the recommended dose of K (8.5 kg/ha) applied for 90 and 105 day rice, at 7 and 8 weeks after seeding (WAS), respectively.
*** Probability level of significance: # at p=0.05.
**** Probability level of p=0.08.

4.02 t ha$^{-1}$ in plots receiving none of the factors to 6.66 t ha$^{-1}$ in the farmers' plot in 90-day rice and from 3.81 t ha$^{-1}$ in plots with a treatment 001 to 6.66 t ha$^{-1}$ plots receiving all three factors in 105-day rice. This reveals that out of the total non-grain dry matter portion, more than 50% remained in soil in the form of non-straw components. This confirms that the plant stubble from the preceding rice crop other than straw contributes to a higher fraction of soil organic matter in continuous rice production systems, and hence addition of straw would not be essential. These findings may even be applicable to rice crops cultivated in sandy soils where the root system develops deeper in order to uptake more water.

The harvest index, i.e. the fraction of economical yield to total biomass[8], was not significantly influenced by the treatments (Table 4). The harvest index of 90-day rice ranged from 0.30 to 0.39, while it ranged from 0.38 to 0.48 for 105-day rice.

### Net Income

There was a significant effect of treatments on the net income from the rice production in this area. In both varieties, the highest net income was given by the farmers' practice (17,182 LKRs. per ha in 90- day rice and 28,184 LKRs per ha in 105-day rice) (Table 5). Grain yield in the farmers' practice, i.e. in the presence of stubble and half the recommended K without using rice straw was significantly greater than the yield in the control treatment (110) in 90-day rice. The lowest yields were produced by treatments that received neither stubble of the previous crop, straw nor K. The plots that received straw and stubble only (110) gave a moderate net income of 8600 LKRs. per ha, while the application of K increased net income by 4820 LKRs in treatment 111.

In 105-day rice, there was a high net income of 28,184 LKRs per ha in the farmers' practice, which was significantly higher than the rest of the treatments (Table 5). Grain yields in this age group were also higher than the 90-day variety (Table 3). Both treatments 110 and 111 that received straw resulted in a lower net income than the farmers' practice, which was due partly to low grain yields. The lowest net income was from treatments (000) that received neither straw, stubble nor K, while the availability of both organic matter content and K increased grain yield and net income.

## Discussion

Although no comparisons were made between the 90-day and 105-day rice varieties, the latter has inherently a higher production potential than the former. This was clear from the higher tiller production and panicle number per plant and relatively greater 100-grain weight. Although there were no significant effects in grain weight among treatments, slight increases in the yield components collectively added a higher yield potential to the 105-day variety compared to 90-day variety (Table 2 and 3). This is supported by the findings of Wu et al.[11] which compared the yielding capacity of three rice varieties with varying age groups for tillering ability, spikelet density and maturity period, and found these to contribute to a higher yield potential of longer age rice varieties. Matsushima[12] also reported that varieties with inherently higher yield potential attain such high yields through minor adjustments in their yield components. In the current study, there were increases in the number of filled grains per panicle in the farmers' practice as a result of added K nutrition when compared to control, which resulted in higher grain yields.

The farmers' practice consisted of application of N at 3 WAS, but none at the basal dressing. This helps rice seedlings to initially make use of soil N. As reported by Sharma and Mittra [10] application of straw at the first

**Table 5.** Total cost, gross and net income from rice as influenced by the incorporation of straw, stubble and potassium.

| Treatment | Total cost (LKRs ha$^{-1}$) | Gross income (LKRs ha$^{-1}$) | | Net Income (LKRs ha$^{-1}$)*** | |
|---|---|---|---|---|---|
| | | 90-day rice | 105-day rice | 90-day rice | 105-day rice |
| 110* | 17050 | 25650 ± 2024 | 36765 ± 7381 | 8600 ± 2026 (429 ± 101) | 19715 ± 7381 (987 ± 369) |
| 111 | 21065 | 34485 ± 1908 | 39520 ± 856 | 13420 ± 1908 (672 ± 96) | 18455 ± 856 (922 ± 43) |
| 010 | 18285 | 28975 ± 1670 | 32965 ± 2625 | 10690 ± 1670 (536 ± 84) | 14680 ± 2624 (736 ± 131) |
| 011 | 21213 | 31730 ± 5328 | 43320 ± 3145 | 10517 ± 5328 (522 ± 266) | 22107 ± 3145 (1108 ± 157) |
| 001 | 21213 | 24700 ± 6609 | 32965 ± 4795 | 3487 ± 6609 (171 ± 330) | 11752 ± 4796 (589 ± 240) |
| 000 | 18285 | 21565 ± 2907 | 29935 ± 1883 | 3280 ± 2907 (164 ± 145) | 7650 ± 1883 (567 ± 94) |
| 01F** | 19126 | 36290 ± 2820 | 47310 ± 7495 | 17164 ± 2820 (859 ± 141) | 28184 ± 7495 (1409 ± 374) |
| Lsd**** | - | 6408 ## | 7352 ## | 6408 ## (320 ##) | 7352 ## (367 ##) |
| CV% | - | 12.40 | 11.01 | 37.59 | 22.89 |

* Department of Agriculture Recommendation (Control).
** Farmers' practice, in which straw removed and half the recommended dose of K (8.5 kg/ha) applied for 90 and 105 day rice, at 7 and 8 weeks after seeding (WAS), respectively.
*** Values within parenthesis indicates the net income (LKRs.) per average farm size of 0.05 hectare, and US $ 1 = 97 LKRs.
**** Probability level of significance: ## at p=0.01.

ploughing helps release nutrients by decomposition. This process continues for about 30 days. The N requirement of rice with less developed root systems during the initial 3 weeks could be and would have been satisfied by N released from the decomposed plant stubble, without adverse effects on the growth of the crop. The application of N at 3 WAS seemed to coincide with the formation of tillers. Furthermore, both N and K application by top dressing at 7 WAS for 90-day rice, and 8 WAS for 105-day rice coincides with the development of floral buds, flowering and grain filling. A main function of K is unloading sugars from chloroplasts to phloem cells, and from phloem cells into storage cells (grains)[7]. Application of K at basal dressing ensures its availability to the plant during the vegetative period. But soil K released during decomposition of stubble and even with added straw is vulnerable to leaching under the high soil moisture environments in rice fields. Deficiency of K at critical stages of rice growth, such as floral bud development and grain filling can cause drastic yield reductions. In addition, the K released fromrice straw added during land preparation may not remain in rice soils and hence may not be available for rice plants to satisfy their K requirements during a critical period like grain filling due to K leaching. Yuan [13] also suggested that K is usually leached from moisture soil environments and hence in rice soils, which can lead to K deficiency, so split application enhances rice yields. Therefore, availability of K during floral bud development until the end of grain filling increases the filled grain number in panicles and grain weight, as observed in these studies. In addition, the presence of K is known to improve the N use efficiency in rice[14, 15]. These combined effects may have contributed to increased grain yields in the farmers practice in both rice varieties compared to other treatments, including treatments 111 and 011 in which the total K dose was applied at the basal dressing (Table 3).

The availability of K affects the dry matter production and partitioning among plant parts, basically in shoot and root portions. The results also confirm that 3.5 – 4.00 t/ha of stubble is left in soil at the time of harvesting the rice crop. This leaves residual nutrients in soil for the succeeding crop to make use of them. In the farmers' practice, straw and stubble dry weights of the 90- day crop were approximately 2.94 and 3.72 t $ha^{-1}$ , respectively, while in the 105-day crop, these yields were 2.63 and 3.48 t $ha^{-1}$, respectively. The quantity of stubble remaining in the field from the preceding rice crop appeared to have, at least, satisfied the threshold requirement of soil organic matter, thus improving the soil productivity and crop yield. As reported by Ponnamperuma[4], application of rice straw improves the soil organic matter content over the years. However, this may be required only with poor rice crops, when sufficient quantities of stubble are not left in the field due to poor crop root growth due to nutrient imbalance, etc. The farmers' practice in the current study produced around 3.7 t $ha^{-1}$ of plant stubble in the 90-day rice crop and 3.48 t/ha in the 105-day rice crop, and hence may negate the straw addition to the next rice crop.

The gross expenses were higher in the farmers' practice compared to the no control treatment due to application of K fertilizers. The net income was also higher in the farmers' practice than the control regardless of the age group. This was due partly to the increased grain yields. Application of K fertilizer was also much more convenient than incorporation of straw. On the other hand, although net income was computed on a per hectare basis, the average farm size would be around 0.05 ha per farmer. Therefore, the farmers' net income lies below 1500 LKRs per season. This indicates that the rice production continues on the subsistence level and the farmers' practice has shown the potential to gain higher yields than other treatments. With long term experience, the farmers experience yield increases with the application of K fertilizers during flower bud development, which gives benefits until the end of grain filling. Therefore, the farmers have chosen the application of fertilizers as the right technology to avoid K limitation during critical growth periods.

The comparisons between treatments 110 and 111, 010 and 011 and 000 and 001 confirm the benefits of K fertilizer compared to K supplementation with straw. Furthermore, the comparison among treatments 000, 010 and 110 shows the importance of and need at least one of the components as organic material. Although the major role of organic matter is to improve the soil condition, the comparison between the farmers' practice with other treatments shows the importance of K fertilization in the presence of stubble of the preceding crop in order to generate satisfactory rice grain yields.

This study also indicates that since the farming is a major determinant of farmers' livelihood, the farmers are most experienced with what they practice and their gains, and hence would prefer to continue with their recognized (appropriate) farming practices. Therefore any change in the farming systems must clearly show its ability to enhance the benefits to the farmers. It is essential that the researchers clearly understand the reasons behind the farmers' traditional approach and its logic, as the farmers need sufficient proof to convince themselves prior to adopting changes recommended by researchers and other information sectors. On the other hand, the success of research could also be enhanced by understanding the farmers' practices and reasons. The farmers are the end users of many developed agricultural technologies, and the benefits or losses of using such technologies must necessarily be accepted by them.

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