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# Hay production from rice (*Oryza sativa* L.) crop to augment fodder resources of Andaman and Nicobar Islands for supporting the livestock production

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**Abstract**

Andaman and Nicobar Islands (ANI) livestock sector performance is severely limited by fodder and feed supplies especially during dry period (January-April) forcing them to feed on low quality paddy straw. In this context, green fodder cum hay production from a tall, long duration, photosensitive rice variety C-14-8 with high biomass production and low grain yields that is widely grown by farmers was assessed to ensure quality fodder supply during 2018 *kharif* season. Six fodder harvest schedules at 15 days interval starting from 60 days after transplanting (DAT) to 120 DAT along with no fodder harvest control as treatments were tested in randomised complete block design (RCBD) with 3 replications for hay production, its quality and economics. Results indicated hay (crude protein) production increased from 4.69 (0.516) to 9.89 (0.787 ) t/ha as harvest schedules got delayed from 60 to 120 DAT. Hay produced from rice green fodder has 2.22, 2.35 and 1.48 times more crude protein, phosphorus and potassium content, respectively than straw. This nutrient dense hay produced would be sufficient to support fodder needs of 2.48 adult cattle units (ACU) during the 4 months rain free period assuming a feeding rate of 15 kg hay/day. Hay cum grain (straw) dual harvest rice production system with hay harvested at 75 DAT has 68.1% higher income than grain (straw) alone producing rice (Rs. 15,300/ha). This was found promising system to augment fodder supplies to dairy animals during dry period.

**Keywords:** Fodder, Hay, Income, Rice equivalent yield, Rice straw

Livestock plays prominent role in livelihoods of everyone through their contributions to human nutrition, draft power and manure (dung and urine) production and account for 4.62% of the total GDP of country i.e., 6,39,912 crores at current prices in 2018-19 (CSO, 2019). Among livestock products, milk accounts for one third of gross income of rural households and milk value in Indian agri and food sector was found not only the highest but also more than combined value of wheat and rice (Chellappa and Haran, 2018). Livestock production in general and dairying in particular in Andaman and Nicobar Islands (ANI) suffers from severe shortage of feed and fodders due to no cultivation of feed producing crops (maize grain, soybean and groundnut oil cakes) and meagre area of cultivated fodders (10 ha), respectively. Dairy farming based on feeding of crop residues (paddy straw etc.) and grazing on poor quality grasses in islands is leading to low milk production and thus per capita availability of milk in ANI is 123.65 g/person/day (DOES, 2018) as compared to national availability of 351 g/person/day in 2016-17 (Economic Survey, 2016-17). Sufficient moisture for fodder production is available only during May to December however, land allocation is low because of meagre cultivated area (40,500 ha). Rice, the sole staple cereal crop, cultivated in the Islands during *kharif* season, supplies straw to livestock feeding. Straw is considered as counterproductive to milk production and lactose concentration in milk (Wang *et al.,* 2014) on account of low glucose (Wang *et al.,* 2016 a), methionine and leucine amino acid supplies (Wang *et al.,* 2016 b). Hence, in Asian countries like Japan, rice is cultivated for hay, haylage and silage production in light of surplus grain production. However, this is not feasible in Islands as rice production is far behind its demand. In Islands, farmers harvest rice crop for green fodder once and manage the regrowth for grain production from C-14-8 variety. This variety, a Japanese introduction in 1940s with its tall stature (>2.0 m), photosensitive nature and long duration (>180 days) suits to prolonged rainy season of Islands and spread over 70% of rice area (Subramani *et al.,* 2014). Fodder harvest schedules without hampering grain production while overcoming lodging problems of this variety was perfected (CIARI, 2016; 2017). As the huge quantity of green fodder harvested can't be used in a day or two, its preservation as silage, haylage and hay without losing quality needs attention. Hay making ( drying to 8-10% moisture) is easier than silage and haylage preparation in islands weather with frequent rains and the simplicity of technique (drying) leads to adoption by farmers easily. Studies on napier grass *(Pennisetum purpureum)* has indicated the utility of silage and hay as dry season fodders in Thailand and hay was found better preservation technology than silage (Mapato and Wanapat, 2018). Hay produced by rice from harvest at vegetative growth stage was found more nutritious (8-10% crude protein) than straw (4% crude protein), a by-product of grain crop. Taking above facts into consideration, hay production was attempted from the fodder cum grain producing paddy to augment quality fodder resources to livestock during dry period. The nutrient quality of hay and straw were compared and economics of hay - grain system was compared with the grain alone production system.

**Materials and Methods**

***Study site and design:*** Field study was conducted during July 2018 – February 2019 at Bloomsdale Research Farm of ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman and Nicobar Islands ($11^0$ 38' 06" N, $92^0$ 39' 15'' E and 14 m amsl). The temperature recorded during the growing period was 24.1 $^o$C and 34.2$^o$ C for minimum and maximum, respectively and the humidity was 75.0% (minimum) and 77.1% (maximum). The rainfall was 201.5 cm in 91 days during July-December, 2018. Cyclone Pabuk has resulted in heavy rains leading to crop lodging from January 5-7, 2019.

The experimental field had clay loam soil (top 20 cm depth) with pH6.2 (near neutral in reaction), and was rated as medium for organic carbon (0.613%), available nitrogen (260 kg/ha) and phosphorous (10.2 kg/ha) and low for available potassium (119 kg/ha) at the start of experiment in July 2018. Six fodder harvest schedules *viz.*, fodder harvest at 60, 75, 90, 105 and 120 DAT along with no fodder harvest control *i.e.*, grain harvest alone of rice as treatments were evaluated in randomized complete block design (RCBD) and treatments (plot size of 20 $m^2$ ) with four replications.

***Crop management*:** The experimental field was prepared by three time puddling followed by manual levelling and experimental lay out. Thirty days aged 'C-14-8' rice seedlings (2-3) were manually transplanted in rows x columns at 20 cm x 15 cm apart on 2$^{nd}$ August 2018. Fertilizer dose was 100, 26.4, 36 kg/ha N, P, K in the form of prilled urea, single super phosphate and muriate of potash, respectively. Whole P and K fertilizers were applied during last puddling. Nitrogen was top dressed in 3 equal splits at 5, 25 and 45 DAT in grain crop. Fodder harvest treatments received N splits on 5, 45 DAT and immediately after fodder harvest. Crop was grown under rainfed conditions with supplemental irrigation to maintain a standing water of 5 cm from 3$^{rd}$ DAT. After fodder harvest as per the treatment, rice crop regrowth was managed for grain production. The field was dewatered to a thin layer prior to N top dressing and watered again two days later. Field was also drained off prior to harvest of fodder as per treatment and also 15 days prior to grain crop harvest. Weeds were managed through two hand weedings at 25 and 45 DAT in all treatments. Need based plant protection measures were given to the crop against insect pests and diseases. Crop was not harvested for fodder in control and in other treatments it was harvested between 15$^{th}$ January -11$^{th}$ February, 2019 (120 DAT fodder harvest treatment) for fodder.

***Observations*:** Plant height (cm) and number of tillers / hill were recorded for 5 selected hills. The biomass from each plot as per treatment was harvested. One kg green fodder sample (triplicate) was dried at 60$^0$C for 48 hours. Grain crop growth, yield attributes and yield were recorded as per standard procedures. The dried rice fodder *i.e.*, hay was subjected to chemical analysis.

**Table 1.** Growth attributes, green fodder, hay yield and its dry matter content of rice as influenced by fodder harvest schedules

| Fodder harvest | Plant height (cm) at harvest | Tiller /hill | Green fodder yield (t/ha) | Hay yield (t/ha) | % dry matter in fodder / hay |
|---|---|---|---|---|---|
| 60 DAT | 170.2 | 16.30 | 16.75 | 4.69 | 28.00 |
| 75 DAT | 192.4 | 14.95 | 21.50 | 6.34 | 29.49 |
| 90 DAT | 198.6 | 13.90 | 23.96 | 7.42 | 30.97 |
| 105 DAT | 203.5 | 12.80 | 28.51 | 8.92 | 31.29 |
| 120 DAT | 210.5 | 11.45 | 30.43 | 9.89 | 32.50 |
| SEm± | 3.15 | 0.62 | 1.02 | 0.43 | 0.33 |
| CD (P=0.05) | 9.71 | 1.910 | 3.142 | 1.325 | 1.016 |

**Table 2.** Yield attributes of grain crop of rice as influenced by fodder harvest schedule

| Fodder harvest | Plant height (cm) at harvest | Panicles/hill | Grains/panicle | Test weight (g) | Days to maturity* |
|---|---|---|---|---|---|
| 60 DAT | 202.6 | 10.51 | 111 | 25.1 | 199 |
| 75 DAT | 191.0 | 10.02 | 112 | 25.0 | 200 |
| 90 DAT | 182.1 | 9.90 | 110 | 25.0 | 205 |
| 105 DAT | 170.6 | 8.44 | 106 | 24.9 | 208 |
| 120 DAT | 155.0 | 6.68 | 95 | 24.7 | 225 |
| No fodder harvest | 230.0 | 10.80 | 115 | 25.2 | 199 |
| SEm± | 2.84 | 0.35 | 2.1 | 0.17 | 2.5 |
| CD (P=0.05) | 8.56 | 1.055 | 6.3 | NS | 7.5 |

*Seed to seed

***Chemical analysis*:** The nutrient concentration (N, P and K) of hay and straw was estimated as per procedures of Singh *et al.* (2005) and the crude protein content (%) was estimated by multiplying N concentration of the plant (%) with 6.25. Crude protein yield was estimated as product of hay/straw yield (kg/ha) and protein content (%) /100. System productivity as rice equivalent yields (REY) was estimated as a product of economic yield (t/ha) i.e. hay, grain and straw.

***Economics and efficiency measures*:** Minimum support price (MSP) of rice grain (Rs. 17,500/t) and an assumed price of Rs. 1,500 and Rs. 4,000/t of rice straw and hay were taken into consideration. Total income arrived from the hay, grain and straw was divided by the price of rice grain and reported as REY. Per day productivity (kg/ha-day) was worked out from REY / crop duration (days). The analysis of variance and statistical interpretation of treatments was done as per Gomez and Gomez (1984).

## Results and Discussion

***Growth attributes of fodder crop*:** Growth attributes, green fodder, hay yield of rice and dry matter content (%) of hay data is presented in Table 1. The plant height increased significantly with age of crop at fodder harvest from 60 to 75 DAT, however the tiller number decreased on delayed fodder harvests beyond 60 DAT. Plant height recorded with 120 DAT was significantly higher than harvest at 90 DAT. Fodder harvest at 120 DAT had lowest tillers/hill (11.45) that was significantly lower than that of 90 DAT harvest. Plant height increases with age up to flowering as a part of growth phenomenon. The decrease in tiller number from 75 DAT could be ascribed to mortality of earlier formed tillers and their senescence.

***Fodder and hay production***

Despite significant reduction in tiller numbers, 120 DAT fodder harvest produced significantly higher green fodder and hay (30.43 and 9.89 t/ha) over all other fodder harvest schedules. There was 1.82 and 2.11 times increase in green fodder and hay production between harvest at 60 and 120 DAT, respectively. Greater increase in hay yield as compared to green fodder could be ascribed to increase in dry matter content of plants with age. This was evident from the fact that at 60 DAT harvest, rice plants were tender with more leaves and low DM content (28.0%) while 32.5% at 120 DAT harvest with more contribution to dry matter from stems rather than leaves.

### Grain crop

***Growth attributes:*** Growth and yield attributes (Table 2) of rice was greatly affected by fodder harvest schedules. Control (No fodder harvest rice) produced significantly taller plants (230 cm) than fodder harvest treatments. Fodder harvest treatments irrespective of its stage significantly reduced plant height of grain crop raised on regrowth and the reduction ranged from 27.4 cm in 60 DAT to 75 cm in 120 DAT fodder harvest. With delayed fodder harvest, active vegetative growth duration available prior to flowering was reduced, and thus had shorter plant heights. On account of reduced plant height with fodder harvest, less biomass was produced by grain crop. These reductions in plant height and biomass contributed to reduced lodging problem that is serious constraint of C-14-8 rice. Complete lodging of grain alone crop was reduced to minimal level with fodder harvest after 75 DAT.

***Yield attributes*:** Panicles and number of grains/panicle production were not affected by fodder harvest at 60 (10.51) and 75 DAT (10.02). Delaying fodder harvest further (90 to 120 DAT) resulted in significant reduction in panicle production and thus, 120 DAT fodder harvest treatment had lowest number of panicles/hill (6.68). Test weight was not altered by fodder harvest schedules, but grains/panicle was significantly influenced by fodder harvest at 105 and 120 DAT over no fodder harvest crop. Further, fodder harvest at 120 DAT had significantly lower number of grains/ panicle (95) than other fodder harvest schedules. Reduction in panicle production with fodder harvest between 90 and 120 DAT was due to loss of vigour in plants for regeneration. Though tillers were produced in delayed fodder harvest, many of them failed to bear panicles. Fodder harvest at 120 DAT enhanced the rice crop duration significantly over other fodder harvest schedules and no fodder harvest treatments and the increase ranged from 9-26 days. The drastic increase in duration of crop in 120 DAT fodder harvest was due to coincidence of fodder harvest with flowering stage and therefore required 26 more days to produce sufficient biomass and to flower again at appropriate photoperiod.

**Table 3.** Grain, straw yield and harvest index of rice as affected by fodder harvest schedule

| Fodder harvest | Grain yield (t/ha) | Straw yield (t/ha) | Harvest Index |
|---|---|---|---|
| 60 DAT | 2.69 | 10.65 | 0.202 |
| 75 DAT | 2.47 | 10.39 | 0.192 |
| 90 DAT | 2.25 | 9.58 | 0.190 |
| 105 DAT | 2.01 | 8.52 | 0.191 |
| 120 DAT (flowering) | 1.70 | 7.24 | 0.190 |
| No fodder harvest | 2.86 | 11.50 | 0.199 |
| SEm± | 0.091 | 0.30 | 0.005 |
| CD (P=0.05) | 0.274 | 0.904 | NS |

***Grain and straw yields*:** Grain and straw yield (Table 3) were highest in no fodder harvest. Fodder harvested at 120 DAT (flowering) resulted in 40.6 and 37% reduction in grain and straw yields, respectively when compared to no fodder harvest treatment. Higher reduction in grain yield in 120 DAT fodder harvest treatment was ascribed to less number of panicles and fewer grains/panicle as compared to other treatments. The biomass produced in short period (30 days) after fodder harvest was not able to supply metabolites to tillers and thus few tillers got transformed into panicles and panicles have fewer number grains than other treatments. Harvest index did not vary due to fodder harvest schedules of rice and remained static (0.19-0.20).

***System productivity and economics*:** System productivity (t/ha) expressed as rice equivalent yield (REY) and economics (Rs/ha) of rice cultivation under different fodder harvest schedules is given in Table 4. Fodder harvest in rice on an average increased the REY by 26.2% over no fodder harvest (2.86 t/ha). Fodder harvest at 90 DAT recorded highest per day productivity. Increase in per day productivity was due to additional grain production (0.58-0.88 t/ha) from hay while crop duration changes were less (5-26 days). Fodder harvest (hay) increased the cost of cultivation of rice by Rs. 4,971 (60 DAT) to 9,651/ha (120 DAT fodder harvest). However, on account of 0.50 - 0.88 t/ha higher REY, the increased cost of production was more than offset leading to higher net income with fodder harvest than no fodder harvest treatment. The income increases ranged from the lowest of Rs. 3219 in 120 DAT fodder harvest to the highest of Rs. 10,414/ha in 75 DAT fodder harvest treatment over no fodder harvest that has the lowest net income (Rs.15,300). This study considered only production economics of rice crop (hay, grain, straw). If the benefits accrued due to feeding of rice hay to livestock/dairy animals in terms of enhanced milk/meat production are accounted, then fodder cum grain production system would be more profitable.

***Nutritional quality of hay and straw*:** Crude protein (CP) content of hay was significantly higher (Table 5) in 60 DAT fodder harvest than other harvest stages and with every 15 days delay in fodder harvest, CP content decreased significantly. Nitrogen content of rice crop varied with age from the highest values in seedling stage followed by vegetative and reproductive stages (lowest values). The decrease in N concentration of plant with age was due to partitioning of nutrient among different components (leaf, stem and panicle). Crude protein yield from hay ranged from 0.516 (60 DAT) to 0.787 t/ha (120 DAT fodder harvest). Grain crop produced 0.492 t/ha CP from straw. Straw production accounted for 0.33-0.46 t/ha CP yields in fodder harvest treatments. Thus fodder harvest treatments from hay and straw together had 2.24 times higher CP yield as compared to no fodder harvest crop (0.492 t/ha). Similar trend in P and K concentrations of hay as that of CP was seen. The differences in P concentration of hay were significant at 30 days intervals. Potassium concentration of hay decreased significantly with each 15 days delay in harvest from 60 to 120 DAT. Crude protein, P and K concentrations of straw were not altered markedly by fodder harvest schedule. However, late fodder harvest (105 and 120 DAT) had higher CP values (4.53%) than earlier schedules (4.34%) and no fodder harvest crop (4.28). When hay nutrient quality was compared with straw; hay had 1.86 -2.57 times higher crude protein (7.96-11.0%). The corresponding values of P and K concentration of hay over straw are 1.9 - 2.8 and 1.23-1.73 times, respectively.

***Livestock fodder support on dual harvest rice*:** Assuming a hay feeding of 15 kg/ adult cattle unit (ACU), the hay produced from the study (Table 1) can support a

**Table 4.** System productivity as rice equivalent yield (REY), per day productivity and economics (Rs/ha) of rice cultivation under different fodder harvest schedules

| Fodder harvest | REY (t/ha) | Productivity/day (kg/ha-day) | Cost of cultivation | Gross income | Net income | B:C ratio |
|---|---|---|---|---|---|---|
| 60 DAT | 3.36 | 16.9 | 56971 | 74810 | 24839 | 1.44 |
| 75 DAT | 3.54 | 17.7 | 58456 | 77570 | 25714 | 1.44 |
| 90 DAT | 3.70 | 18.1 | 59428 | 79105 | 23997 | 1.40 |
| 105 DAT | 3.71 | 17.8 | 60778 | 77635 | 22857 | 1.38 |
| 120 DAT | 3.74 | 16.6 | 61651 | 76290 | 18519 | 1.30 |
| No fodder harvest | 2.86 | 14.4 | 52000 | 67300 | 15300 | 1.29 |
| SEm± | 0.09 | 0.28 | | | 600 | |
| CD (P=0.05) | 0.30 | 0.85 | | | 1806 | |

**Table 5.** Nutrient composition of rice hay and straw under different fodder harvest schedules

| Fodder harvest | Crude protein (%) | | Crude protein yield (t/ha) | | | P concen-tration (%) | | K concen-tration (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | Hay | Straw | Hay (A) | Straw (B) | Total (A +B) | Hay | Straw | Hay | Straw |
| 60 DAT | 11.00 | 4.32 | 0.516 | 0.460 | 0.976 | 0.28 | 0.103 | 2.85 | 1.66 |
| 75 DAT | 10.28 | 4.34 | 0.652 | 0.451 | 1.103 | 0.25 | 0.105 | 2.66 | 1.63 |
| 90 DAT | 9.56 | 4.37 | 0.709 | 0.419 | 1.128 | 0.24 | 0.104 | 2.57 | 1.68 |
| 105 DAT | 8.63 | 4.51 | 0.770 | 0.384 | 1.154 | 0.21 | 0.110 | 2.38 | 1.63 |
| 120 DAT | 7.96 | 4.55 | 0.787 | 0.329 | 1.117 | 0.19 | 0.112 | 2.01 | 1.64 |
| No fodder harvest | - | 4.28 | - | 0.492 | 0.492 | - | 0.099 | - | 1.64 |
| SEm± | 0.205 | 0.076 | 0.09 | 0.046 | 0.10 | 0.011 | 0.004 | 0.049 | 0.10 |
| CD (P=0.05) | 0.630 | NS | 0.27 | 0.140 | 0.308 | 0.035 | NS | 0.150 | NS |

cattle for 187 (60 DAT fodder harvest) – 396 days (120 DAT fodder harvest). If demand for quality fodder only during rain free period (January-April) is considered (*i.e.*, 120 days), 1.56 -3.30 ACU can be supported from one ha. Straw production from rice when fed at an assumed rate of 10 kg/ACU/day, grain alone crop can support 3.15 ACU year round. Straw produced in fodder cum grain system can support 1.98 (120 DAT fodder harvest) to 2.91 ACU/ year (60 DAT fodder harvest). In nutshell, hay cum grain producing system can support livestock nutritionally better than straw feeding. It may give substantial support to dairy animals in islands that otherwise was severely constrained by fodder.

## Conclusion

From the study it is concluded that fodder harvest for hay production can be taken from long duration, tall and photosensitive C-14-8 variety of rice crop popular in the Andaman and Nicobar Islands up to 120 DAT, however, it is economical to manage the fodder harvest at 75 DAT when rice crop economics alone are accounted. However, when we consider the animal productivity gains also, 120 DAT fodder harvest for hay production would become more economical. Hay feeding trails need to be conducted for validating the impact of hay cum grain production system of rice on supporting dairy farming.

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