Bangladesh J. Nuclear Agric., 39(1): 77-86, 2025 *ISSN 0258-7130*
DOI: https://doi.org/10.3329/bjnag.v39i1.83340

EFFECTS OF NUTRIENT MANAGEMENT ON PRODUCTIVITY OF T. AMAN-MUSTARD (RELAY CROP)-BORO RICE PATTERN

M.A. Haque[1], R. Ashrafi[1*] and K. Nahar[1]

Abstract

An experiment was conducted to find out the effects of different doses of chemical fertilizers along with the integrated use of vermicompost in a three crops cropping pattern [T. aman-Mustard (relay crop)-Boro] and to find out the optimum fertilizer doses of mustard under relay crop and for the cropping system as well at the BINA Sub-station farm, Ishwardi during 2023 to 2024. Mustard was grown as relay crop with T. aman. Six treatments for each of the three component crops were used comprising different doses of NPKS along with or without vermicompost. The experiment was laid out in a randomized complete block design with three replications. In the first crop of the cropping pattern, treatment T_3 (100% P from VC+100% NKS from CF as IPNS) produced maximum grain yield (6.5 tha^{-1}) of T. aman rice followed by the treatment T_5. In the second and third crop of the cropping system, the treatment T_4 (125% NPKS) produced the highest yield. The fertilizer doses (kg ha^{-1}) for the component crops were $N_{75}P_0K_{26}$ S_7 VC_{352}, $N_{107}P_{24}K_{54}S_{22}Zn_2B_2$ and $N_{161}P_{18}K_{67}S_{13}$ appeared suitable for T. aman, Mustard and Boro, respectively, based on yield performance and economic analysis.

Key words: Relay crop, Mustard, Fertilizer dose, T. Aman, Boro

Introduction

Ensuring global food security with changing environment and shrinking natural resources are the major challenges in the present era. In the scenario of conventional farming system, limited chances are available to cope with these issues. Relay cropping is a complex suite of different resource-efficient technologies, possesses the capability to improve soil quality, to increase net return, land equivalent ratio, and to control the weeds and pest infestation (Tanveer *et al.,* 2017). Relay cropping promotes high yield and land-use efficiency by allowing a double harvest (Xu *et al,* 2022). In relay cropping system, crops are planted on different dates and cultivated together for at least part of their life cycle. Relay cropping is a sustainable approach that optimizes system productivity and compensates yield of two crops at a time and can solve time contravene among sowing of different crops. It enhances soil quality, limits weeds and pest attack, enhances the efficient use of available resources, saves money and time, utilizes residual fertility, prevents soil degradation and thus increases farm profits (Tanveer *et al.,* 2017). Soil quality is highly dependent on soil management practices, and it influences crop production. Cropping patterns, which involve the arrangement and sequence of crops, play a crucial role in maintaining soil fertility and overall farm productivity. Cropping patterns, especially when incorporating techniques like

[1]Soil Science Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh-2202
***Corresponding Author:** reema_asharafi@yahoo.com

relay cropping, significantly influence crop productivity and soil fertility. Meeting the challenge of ensuring food security through horizontal expansion of land is not possible due to a decrease in agricultural land. Productivity of the crops should be increased through adoption of improved technologies and cropping pattern might be of one among them. So, intensifying the land use system through multiple cropping or by growing more and more crops on the same piece of land in a calendar year is a promising option to feed these teeming millions (Barman *et al.,* 2021).

The cropping patterns of Bangladesh are mainly rice-based. Increase of cropping intensity in rice-based cropping system is very important for maximizing land use efficiency as well as increasing the yield per unit land area through manipulating the limited land resources. Cropping intensity may be increased by inclusion of non-rice crops like mustard, jute, mung bean, field pea, vegetables etc. and undertaking some special management practices in the existing rice based cropping system (Razu *et al.,* 2023). The total cropped area of mustard and rape seed production in Bangladesh is 330730.494 ha, with a yield of 0.203 t ha-1 and total production of 409659.06 metric tons (BBS, 2023). However, the advantage of including extra crops in rice based cropping system could depends upon the selection of variety and appropriate agronomic management practices such as fertilizer management (Hossain *et al.,* 2014). More than 50% of our cultivated soil contains organic matter below the critical level (1.5%) (Mollah *et al.,* 2008). For maintaining of soil fertility and attainable crop yield, it is required to apply proper amount of fertilizers. High and medium high land is in most cases deficient in most essential macro-nutrients such as nitrogen, phosphorus, potassium and sulphur. The low organic matter content, higher cropping intensity, improper cropping sequence and faulty management practices are the major causes of depletion of soil fertility. Imbalance use of fertilizer is another serious problem in our country. Imbalanced use of inorganic fertilizers and soil nutrient mining has resulted in declining soil fertility and therefore, stagnating or decreasing of crops yields. Previous survey revealed that farmers in many areas in Bangladesh applied nitrogenous fertilizer higher than the recommended dose for some crops. They usually did not use any organic fertilizers. Combined application of inorganic fertilizers and organic manures improved the physical properties and available nutrient status in soils. Continuous application of inorganic fertilizers alone causes soil organic matter degradation, soil acidity or alkalization, soil deterioration and environmental pollution. Integrated or mixed inorganic and organic nutrient management system is an alternative system for the sustainable and cost-effective management of soil which improves soil properties and increase soil fertility without affecting environment (Titirmare *et al.,* 2023).

In this connection a cropping pattern experiment was conducted considering mustard as relay crop with T. aman attempted to determine better fertilizer doses considering yield performance and economic potentiality of T. aman, mustard and Boro crops of the cropping pattern. Therefore, field experiments were conducted to investigate the effect of different doses of chemical fertilizers with the integrated use of vermicompost in 3 crops cropping pattern [T. aman-mustard (relay crop)-Boro] and to find out optimum fertilizer doses of mustard under relay crop as well as the whole cropping pattern.

Materials and Methods

An experiment was conducted to find out the effects of different doses of chemical fertilizers with the integrated use of vermicompost in 3 crops of the T. aman rice-mustard (relay crop)-Boro rice pattern at the BINA Sub-station, Ishwardi during 2023 to 2024. Six treatments were used for each crop as follows:

For T.aman rice (Binadhan-17)
T_1 : 100% PKS from chemical fertilizer (CF);
T_2 : 100% NPKS from CF;
T_3 : 100% P from VC + 100% NKS from CF (IPNS);
T_4 : 100% P from VC + 100% NKS from CF (non-IPNS);
T_5 : 50% K from VC + 50% K from CF +100% NPS from CF (IPNS) and
T_6 : 50% K from VC + 50% K from CF + 100% NPS from CF (Non-IPNS)

Tor Mustard (Binasharisha-11) and Boro rice (Binadhan-14)
T_1 : Native soil fertility
T_2 : 100% NPKS
T_3 : 75% NPKS
T_4 : 125% NPKS
T_5 : 150% N + 100% PKS and
T_6 : 75% NPKS + 2 t ha^{-1} VC

The experiment was laid out in a randomized complete block design with three replications. Mustard was grown as relay crop with T. aman before 14 days of harvesting of T. aman rice. In the three crops cropping pattern, Boro rice Binadhan-14, T. aman short duration rice variety Binadhan-17 and mustard variety Binasarisha-11 were used. Sowing period of mustard is very short and T. aman rice is generally occupies the land before the sowing of mustard. Therefore to adjust the sowing period of mustard, it was planned for cultivating as relay crops with T. aman rice. Mustard was sown in T. aman plots at 14 days before harvesting of T. aman rice (standing T. aman rice). The details of crop management of different crops under cropping pattern are shown in the Table 1.

Table 1. Spacing, sowing & harvesting time and crop duration of the varieties of crops in the cropping pattern

Crop	Variety	Spacing	Date of sowing/transplanting	Date of harvesting	Field duration (days)
T. Aman	Binadhan-17	20cm x 15cm	09/08/23 (transplanting)	17/11/2023	100
Mustard	Binasarisha-11	Broadcasting	03/11/2023 (14 days before harvesting of T. Aman rice)	01/02/2024	76 (90)
Boro	Binadhan-14	20cm x 15cm	07/03/2024 (transplanting)	02/07/2024	118

Fertilizer rates were applied as per to the treatments (Table 2). Intercultural operations were done as and when necessary. Fertilizer rates were applied on the basis of soil test. In case of manure treatments, IPNS was followed i.e. chemical fertilizer N,P,K and S were balanced according to nutrients supply from vermicompost in respective cases. Therefore, N,P,K and S were also reduced from CF treatments from all the crops.

Initial soil properties and nutrient contents in vermicompost applied in the experiment were analyzed initially. Texture, pH, OC, total N,P,K and S were observed silt loam, 7.4, 1.2%, 0.11%, 17 μgg^{-1}, 0.185 meq% and 15.4 μgg^{-1} respectively. Nutrient contents i.e N,P,K and S were of vermicompost were observed 1.4%, 0.65%, 3.5% and 0.5% respectively. Vermicompost and all chemical fertilizers (TSP, MoP and gypsum) were applied during final land preparation except urea in case of T. aman and Boro rice. Urea was applied in three equal splits. Vermicompost and first split of urea with other fertilizers (TSP, MoP, gypsum, Zinc sulphate and Boron) were applied in mustard just after harvesting of T. aman rice and 2nd split of urea was applied at 30 days after sowing of mustard. Data recorded from T. aman and Boro were plant height, number of effective tillers, panicle length and number of filled grain from randomly selected five plants while grain and straw yields were recorded from 10 m^2 of land. From mustrad plant height, number of siliquae, seeds per siliqua from randomly selected five plants while seed and straw yields were recorded from 10 m^2 of land. An analysis of variance (ANOVA) was performed using Statistix 10 software. Mean comparisons of the treatments were conducted using the least significant difference (LSD) test with a level of significance of $p \leq 0.05$. Economic analysis was also performed to determine BCR of each crop and finally whole cropping pattern.

Table 2. Fertilizers and vermicompost rates for T. aman rice (Binadhan-17), mustard (Binasharisha-11) and Boro rice (Binadhan-14)

Treatments	Chemical Fertilizer (CF) (kg ha^{-1})						Vermicompost (kgha^{-1})
	N	P	K	S	Zn	B	
	T. aman rice (Binadhan-17)						
T_1: 100% PKS from chemical fertilizer (CF)	0	7	39	9			0
T_2: 100% NPKS from chemical fertilizer (CF)	84	7	39	9			0
T_3: 100% P from VC+100% NKS from CF (IPNS)	75	0	26	7			352
T_4: 100% P from VC+100% NKS from CF (non-IPNS)	84	0	39	9			352
T_5: 50% K from VC +50% K from CF+100% NPS from CF (IPNS)	71	0	20	6			527
T_6: 50% K from VC + 50% K from CF+100% NPS from CF (Non-IPNS)	84	7	20	9			527
	Mustard (Binasarisha-11)						
T_1: Native soil fertility	0	0	0	0	0	0	0
T_2: 100% NPKS	107	24	54	22	2	2	0
T_3: 75% NPKS	81	18	40	16	2	2	0
T_4: 125% NPKS	134	30	67	27	2	2	0
T_5: 150% N + 100% PKS	161	24	54	22	2	2	0
T_6: 75% NPKS + 2 t/ha VC	81	18	40	16	2	2	2000
	Boro (Binadhan-14)						
T_1: Native soil fertility	0	0	0	0	-	-	0
T_2: 100% NPKS	129	14	54	10	-	-	0
T_3:75% NPKS	97	11	40	8	-	-	0
T_4:125% NPKS	161	18	67	13	-	-	0
T_5:150%N + 100% PKS	193	14	54	10	-	-	0
T_6:75% NPKS+ 2 t/ha VC	97	11	40	8	-	-	2000

Results and Discussion

T. aman rice

The results stated that yield and yield contributing characters of T. aman rice responded significantly to the application of vermicompost and chemical fertilizers except panicle length (Table 3). The treatment T_3 produced maxuimum grain yield (6.5 tha-1) of T. aman rice followed by the treatment T_5 (6.2 t ha^{-1}). The result indicated that chemical fertilizer with incorporation of vermicompost produced statistically higher grain yields than the sole application of 100% CF and treatment T_1 (4.9 t ha^{-1}) in T. aman rice. Considering other yield contributing characters, effective tiller $hill^{-1}$ and numbers of filled grain were also found maximum in the treatment T_3 except plant height and straw yield of T. aman rice. Rahman et al. (2013) also found that combined application of organic and inorganic sources of nutrient to soils increased the use efficiencies of production inputs and also increased crop yields.

Table 3. Effects of vermicompost with chemical fertilizer on the yield and yield contributing characters of T. aman (Binadhan-17) during 2023-24

Treatments	Plant height (cm)	Panicle length (cm)	Effective tiller $hill^{-1}$ (no.)	Filled grain $panicle^{-1}$ (no.)	Grain yield (tha^{-1})	Straw yield (t ha^{-1})
T_1: 100% PKS from chemical fertilizer (CF)	82.1 c	21.6	07.3 d	158 e	4.9 d	3.0 c
T_2: 100% NPKS from CF	92.1 a	22.7	09.6 c	175 c	5.6 b	4.5 ab
T_3: 100% P from VC+ 100% NKS from CF (IPNS)	84.3 bc	22.0	11.3 ab	189 a	6.5 a	4.6 ab
T_4: 100% P from VC +100% NKS from CF (non-IPNS)	86.4 b	22.0	11.0 b	172 c	5.5 bc	4.0 b
T_5: 50% K from VC +50% K from CF +100% NPS from CF (IPNS)	91.1 a	21.5	09.6 c	182 b	6.2 a	5.0 a
T_6: 50% K from VC + 50% K from CF+100% NPS from CF (Non-IPNS)	84.3 bc	22.2	12.3 a	167 d	5.1 cd	4.7 ab
$Sig_{0.05}$	*	NS	*	*	*	*
CV (%)	5.39	5.66	6.60	11.02	8.82	9.75

In a column, figures having common letter(s) do not differ significantly at 5% level of probability as per DMRT, CV= Coefficient of Variation, NS= Not-significant. DMRT= Duncan's New Multiple Range Test.

Profitability analysis of T. aman production with different doses of fertilizers is presented in the Table 4. The treatment T_3 also showed the highest gross margin with gross return and BCR. The highest gross margin was estimated 169994.2 Tk. ha^{-1} with gross return 229800.00 Tk. ha^{-1} and BCR 2.84 in the treatment T_3. According to the profitability the treatments could be arranged in order of $T_3>T_5>T_2>T_4>T_1>T_6$. Among six treatments, the treatment T_3 was the most profitable treatment for T. aman (Binadhan-17) in the experiment.

Table 4. Cost and return analysis of T. Aman at different treatments of chemical fertilizer and vermicompost

Treatment	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1: 100% PKS from chemical fertilizer (CF)	173000	57262.2	115737.8	2.02
T_2: 100% NPKS from CF	198250	62183.76	136066.2	2.19
T_3: 100% P from VC + 100% NKS from CF (IPNS)	229800	59805.85	169994.2	2.84
T_4: 100% P from VC + 100% NKS from CF (non-IPNS)	194500	61238.76	133261.2	2.18
T_5: 50% K from VC + 50% K from CF + 100% NPS from CF (IPNS)	219500	59140.69	160359.3	2.71
T_6: 50% K from VC + 50% K from CF +100% NPS from CF (Non- IPNS)	180850	61347.76	119502.2	1.95

Chemical fertilizer combined with vermicompost produced statistically higher yields than the sole application of chemical fertilizer. The treatment T_3: 100% P from VC + 100% NKS from CF (IPNS) reduced 100% application of P fertilizer and also estimated highest gross margin with gross return and BCR compared to other treatments. The results revealed that the treatment T_3: 100% P from VC+ 100% NKS from CF (IPNS) might be good option for the cultivation of T. aman rice.

Mustard

Yield and yield contributing characters of mustard such as seed and straw yield, siliqua plant^{-1} and seeds siliqua^{-1} were significantly influenced with the integrated use of vermicompost and inorganic fertilizers (Table 5). The result indicated that increased amount of all fertilizers gave higher yields than the lesser increased N or vermicompost alone. The treatment T_4 (125% NPKS) produced maximum seed yield of mustard (1.02 tha^{-1}) followed by the treatment T_5 (150% N+100% PKS). But the seed yield of all the treatments showed statistically similar result except the treatment T_1 (native soil fertility). The treatment T_1 produced lowest seed yield (0.21 t ha^{-1}) of mustard. All the yield contributing characters were maximum in the treatment T_4 except plant height. The results revealed that 25% more NPKS than 100% recommended fertilizer was needed to get better yield of mustard in relay cropping system.

Profitability analysis of mustard production also estimated highest gross return in the treatment T_4 treatment (78670 Tk. ha^{-1}), but gross margin and BCR were found highest in the treatment T_2 (45015 Tk. ha^{-1} and BCR 1.47) (Table 6). According to gross margin the treatments could be arranged in order of $T_2>T_4>T_5>T_3>T_6>T_1$. Among six treatments, the treatment T_2 is the most profitable treatment for mustard production in relay cropping system. So, for getting higher gross margin with higher BCR rate, the treatment containing

100% NPKS i.e. recommended fertilizer was selected as the best treatment to get high yield with highest economic benefit of mustard in relay cropping system.

Table 5. Effects of vermicompost with chemical fertilizer on the yield and yield contributing characters of mustard (Binasarisha-11) during 2023-24

Treatments	Plant height (cm)	Siliqua plant^{-1} (no.)	Seeds siliqua^{-1} (no.)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: Native soil fertility	64.7 d	15.0 e	17.0 c	0.21 b	0.98 d
T_2: 100% NPKS	92.8 a	31.0 c	21.3 b	0.98 a	2.17 a
T_3: 75% NPKS	81.0 c	25.3 d	21.7 b	0.94 a	1.94 b
T_4: 125% NPKS	82.0 c	49.6 a	24.3 a	1.02 a	2.17 a
T_5: 150% N + 100% PKS	88.6 b	31.3 c	21.7 b	1.00 a	2.15 a
T_6: 75% NPKS+ 2 t/ha VC	80.6 c	33.7 b	22.0 b	0.96 a	1.75 c
$Sig_{0.05}$	*	*	*	*	*
CV (%)	6.62	7.68	12.54	11.61	10.81

In a column, figures having common letter(s) do not differ significantly at 5% level of probability as per DMRT.CV= Coefficient of Variation, NS= Not-significant. DMRT= Duncan's New Multiple Range Test.

Table 6. Cost and return analysis of mustard

Treatment	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1: Native soil fertility	16730.00	8763.00	7968	0.91
T_2: 100% NPKS	75670.00	30655.00	45015	1.47
T_3: 75% NPKS	64940.00	26705.00	38235	1.43
T_4: 125% NPKS	78670.00	34453.00	44217	1.28
T_5: 150% N + 100% PKS	77150.00	33819.00	43331	1.28
T_6: 75% NPKS+ 2 t/ha VC	73750.00	50705.00	23045	0.45

Boro rice

Yield and yield contributing characters such as grain yield, straw yield, effective tiller, filled grain of Boro rice were significantly influenced with the application of vermicompost and inorganic fertilizers (Table 7). The treatment T_4 produced the highest grain yield (6.2 t ha^{-1}) of Boro rice followed by the treatment T_5 (6.0 t ha^{-1}). The result indicated that increased amount of all fertilizers produced higher yields. The treatment T_1 produced lowest grain yield (3.0 t ha^{-1}) of Boro rice. All the yield contributing characters showed significantly the highest scores at the treatment T_4.

The results revealed that 25% more NPKS than recommended fertilizer is needed to get better yield in Boro rice. These results were also supported by the findings of Barman et al. (2019) and concluded that Soil Test Basis (STB) fertilizer + 25% extra NPK performed better than all other fertilizer levels and could be used for potato- Boro-T. aus-T. aman cropping pattern.

Table 7. Effects of vermicompost with chemical fertilizer on the yield and yield contributing characters of Boro rice (Binadhan-14) during 2023-24

Treatments	Plant height (cm)	Panicle length (cm)	Effective tiller hill^{-1}	Filled grain panicle^{-1}	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
T_1 = Native soil fertility	70.8 c	20.40	7.0 c	83 d	3.0 e	4.2 c
T_2 = 100% NPKS	86.4 b	22.23	11.0 a	123 ab	5.1 c	5.5 a
T_3 = 75% NPKS	85.9 b	21.93	9.0 b	113 c	4.4 d	5.1 b
T_4 = 125% NPKS	88.1 ab	22.27	11.0 a	127 a	6.2 a	5.7 a
T_5 = 150% N + 100% PKS	86.4 b	22.20	11.0 a	123 ab	6.0 b	5.6 a
T_6 = 75% NPKS+ 2 t/ha VC	90.4 a	22.13	11.0 a	120 b	5.9 b	5.6 a
$Sig_{0.05}$	*	NS	*	*	*	*
CV (%)	6.47	8.04	10.16	7.27	8.13	10.3

In a column, figures having common letter(s) do not differ significantly at 5% level of probability as per DMRT.CV= Coefficient of Variation, NS= Not-significant. DMRT= Duncan's New Multiple Range Test.

According to profitability analysis of Boro rice production with different doses of fertilizers, treatment T_4 also showed highest gross margin with gross return and BCR (Table 8). Highest gross margin was estimated 138271.00 Tk. ha^{-1} with gross return 219850.00 Tk. ha^{-1} and BCR 1.69 in T_4 treatment. According to estimated gross margin the treatments could be arranged in order of T_4>T_5>T_6>T_2>T_3>T_1. Among six treatments, the treatment T_4 is the most profitable treatment for Boro rice. The results revealed that 25% more NPKS than recommended fertilizer was needed to get higher yield and economic benefit of Boro rice.

Table 8. Cost and return analysis of Boro at different fertilizer treatment

Treatment	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1: Native soil fertility	107100.00	64600.00	42500.00	0.66
T_2: 100% NPKS	181250.00	78092.00	103158.00	1.32
T_3: 75% NPKS	156550.00	74863.00	81687.00	1.09
T_4: 125% NPKS	219850.00	81579.00	138271.00	1.69
T_5: 150%N + 100% PKS	212800.00	81842.00	130958.00	1.60
T_6: 75% NPKS+ 2 t/ha VC	209300.00	98863.00	110437.00	1.12

Field duration of cropping pattern mainly depends on individual duration of the crop varieties used. The cycle of the cropping pattern was completed in 294 days (field duration) and the turnaround time for the cropping pattern was 71 days (Table 9). As per field duration of individual crop, total days needed for the cropping pattern is 308 which are 14 days more than the cropping pattern grown mustard as relay crop. This demonstrates that relay cropping of mustard with T. aman reduces the total duration to complete the cycle and also offers earlier sowing of mustard. Relay cropping has potential to increase the production level by increasing yield and yield attributes of a crop due to timely sowing of second crop (Tanveer *et al.,* 2017). It was also suggested by Yan *et al.* (2010) that relay cropping ensure timely sowing of the second crop.

Table 9. Sowing/transplanting, harvesting, field duration and turnaround time of different crops of the cropping pattern

Crop	Variety	Dates of sowing/ transplanting	Date of harvesting	Field duration (days)	Turn around time (days)	Time minimizing
T. Aman	Binadhan-17	17/07/23 (sowing) 09/08/23 (transplanting)	17/11/23	100	-	
Mustard	Binasarisha-11	03/11/2023 (14 days before harvesting of T. aman rice)	01/02/24	76 (90)	34	Minimize 14 days sowing time of mustard
Boro	Binadhan-14	12/02/24 (sowing) 07/03/2024 (transplanting)	02/07/24	118	37	

As relay crop, mustard seeds were broadcasted on standing T. Aman field at 14 days before harvesting of T.aman (Table 9). This facilitated 14 days earlier sowing of mustrad and reducing the cost of production by avoiding tillage practices to prepare the field. Among six different fertilizer treatments of three individual crops of the cropping pattern best treatment was considered as T_3, T_2 and T_4 for T. aman, mustard and Boro, respectively based on yield and economic benefit (Table 10). As per these treatments estimated BCR was found 2.84, 1.47 and 1.69 in T. aman, mustard and Boro, respectively. For the whole cropping pattern best treatment was selected on the basis of BCR (Table 4, 6 and 8) for each crop which was stated in the Table 10. BCR for the whole cropping pattern BCR was found 2.06 which demonstrate the cropping pattern is cost effective and potentially acceptable.

Table 10. Cost and return analysis of the cropping pattern of the highest benefited crops among the treatments

Best fertilizer doses among the treatments	Gross return ($Tk.ha^{-1}$)	Total variable cost ($Tk.ha^{-1}$)	Gross margin ($Tk.ha^{-1}$)	BCR
100% P from VC+100% NKS from CF (IPNS) in T.aman	229800	59805.85	169994	2.84
100% NPKS in mustard	75670	30655	45015	1.47
125% NPKS in Boro	219850	81579	138271	1.69
Total CP (Crops of the whole cropping pattern with best treatments)	514590	168090	346499	2.06

Conclusion

It could be concluded that fertilizer doses (kg ha^{-1}) $N_{75}P_0K_{26}S_7VC_{352}$, $N_{107}P_{24}K_{54}S_{22}Zn_2B_2$ and $N_{161}P_{18}K_{67}S_{13}$ were found better considering yield performance and economic potentiality of T. aman rice, mustard and Boro rice, respectively. Cropping pattern with relay cropping of mustard is cost effective (BCR of mustard is 1.47 and BCR of cropping pattern is 2.06) and potentially acceptable. Relay cropping system offers earlier

sowing of mustard which is good option for minimizing the sowing time of mustard and also reduce the total length of T. aman-mustard (relay crop)-Boro rice cropping pattern.

References

Barman, A., Shome, S., Alam, M.J. and Hossain, M.A. 2019. Fertilizer recommendation for four crop based cropping pattern: potato-Boro-T.aus-T.aman under AEZ-11. Bangladesh Agron. J. 22(1):71-78.

Barman A., Shome, S., Khatun, M.R., Mausd, M.M. and Akther, S. 2021. Increasing cropping intensity ad crop productivity of four crops based mustard-Boro-T. aus-T. aman cropping pattern. Bangladesh Agron. J. 24(1):109-117.

BBS. 2023. Area, yield rates and productions of minor crops, Summary crop statistics. Statistics Division, Ministry of Planning. Government of Peoples Republic of Bangladesh.

Hossain I., Mondal, M.R.I., Islam, M.J., Aziz, M.A., Khan, A.S.M.M.R. and Begum, F. 2014. Four crop based cropping pattern studies for increasing cropping intensity and productivity in Rajshahi region of Bangladesh. Bangladesh Agron. J. 17(2):55-60.

Mollah, M.R.A., Khalequzzaman, M., Hossain, M.M. and Rahman, S.M.L. 2008. Cropping pattern based fertilizer recommendation for mustard-Boro-T.aman rice cropping pattern under AEZ-25 at Nandigram, Bogra. J. Soil. Natr. 2(2):31-34.

Rahman, M.M. 2013. Nutrient-use and carbon sequestration efficiencies in soils from different organic wastes in rice and tomato cultivation. Soil Sci. Plant Anal. 4444 (9):1457-1471.

Razu, M., Ibrahim, M. and Islam, S.M.M. 2023. Annual Research Review Workshop 2020-21, xii. Rice Farming System Division Bangladesh Rice Research Institute (BRRI), https://brri.portal.gov.bd/sites/default/files/files/brri.portal.gov.bd/page/5d7cc8e2_ccc0_4756_acd5_0ca39d265adc/2022-12-30-06-37-15fb3ba8fcf285eba394fd4db82c1207.pdf accessed on 12.09.2023.

Tanveer, M., Anjum, S.A., Hussain, S., Cerda, A. and Ashraf, U. 2017. Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production. Environ. Sci. Pollut. Res. 24:6973-6988.

Titirmare, N.S., Ranshur, N.J., Patil, A.H., Patil, S.R. and Margal P.B. 2023. Effect of inorganic fertilizers and organic manures on physical properties of soil: A Review. Int. J. Plant and Soil Sci. 35(19), 1015-1023.

Xu, S., Wang, R., Gasser, T., Ciais, P., Peñuelas, J., Balkanski, Y., Boucher, Q., Janssens, I.A., Sardans, J., Clark, J.H., Cao, J., Xing, X., Chen, J., Wang, L., Tang, X.U. and Zhang, R. 2022. Delayed use of bioenergy crops might threaten climate and food security. Nature. 609 (7926):299–306.

Yan, Y., Gong, W., Yang, W., Wan, Y., Chen, X., Chen, Z. and Wang, L. 2010. Seed treatment with uniconazole powder improves soybean seedling growth under shading by corn in relay strip intercropping system. Plant Prod. Sci. 13:367–374.