Original Research Article

Mode and dose of boron nutrition on growth, productivity, nutrient uptake and quality of a rice-groundnut cropping system

ABSTRACT

To assess the effect of B nutrition on growth, productivity, uptake and crop quality of rice-groundnut cropping system under medium land *Inceptisols*Odisha a field experiments was conducted during kharif and rabi 2016-17 and 2017-18.The experiment was laid out in RBD with eight treatments being replicated thrice.The results revealed that rice crop showed higher growth rate (9.4 mm day^{-1}) than groundnut crop of 9.1 mm day^{-1}. Soil application of B in split doses maintained higher growth rate than foliar spray irrespective of crops. B fertilization to rice crop reduced chaffiness from 35% in no B fertilization to 15% in B applied in split doses. It also showed 15.6 % higher number of nodules than no B application in groundnut crop.Economic yield produced in different mode of B application in rice-groundnut cropping system, the 2nd crop was influenced by 22.5% against 16.0% for the 1st crop.B improved the economic yield by 19.5%over no B application. Application of B@1~~kg ha~~kg.ha^{-1} to each crops increased the economic yield by 8.7 % compared to its half rate application (0.5 ~~kg ha~~kg.ha^{-1}).Based on rice-equivalent yields (REY) of rice-groundnut cropping system practices followed the order: Split application (288)>Full dose basal (250)>Full dose B to groundnut (199)>Half dose B basal to each crop (188)>Full dose B to rice (186) = Foliar spray of B (186)>STD (100). The recovery of added N increased by (42.2%) when B was applied to 1st crop with full dose (53.5%), again it increased further by 60.8% when applied in split. B nutrition to rice-groundnut system influenced P and K uptake by 36.4% and 48.4% respectively over no application.In rice-groundnut cropping system split application of B@0.5 ~~kgha~~kg.ha^{-1}to both crops at active growth stages improved the yield,uptake,crop quality and economic benefit was found superior over no or sub optimal dose of B application in a deficient medium land *Inceptisols* of Jajpur district.

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Key word: Chaffness; Foliar spray; Oil content; Protein content;Split application of B; Sugar; Test weight.

1. INTRODUCTION

Rice and rice-based cropping system are of prime important in South East Asia (Huke ,1997).There has been a decline in productivity of paddy rice in India. Continuous cropping with single crop results in rapid decline in soil fertility and thus requires a serious attention for efficient fertilizer use.Fertilizer recommendations should be for a cropping system instead of a single crop because fertilizer recommendations for a single crop often results in high and uneconomic use of fertilizer in the system due to residual effect of fertilizers[1]. Groundnut is one of the most important oil seed crops [2,3].Paddy is the dominant staple crop in the state of Odisha and Groundnut is the major oilseed crops cultivated in the state. It occupied about 34 % of total oilseed area and contributed more than 68% of total oilseeds production during the triennium ending (TE) 2017-18 (25 years).It has registered a negative growth rate (cropped area) of 0.93% per annum. Production too declined from 466,000 tons to 374,000 tons during the same period [4]. Now a days micronutrients deficiency particularly boron is widespread in rice growing areas of Odisha that leads to substantial loss in yield and quality of grains. Boron can influence photosynthesis, respiration and activate number of enzymatic systems of protein and nucleic acid metabolism in plants [5].Boron deficiency may induce grain sterility in crops. Usually, dicots have higher boron requirement than monocots.In Odisha boron deficiency in surface soil accounts for 52%. Recent studies indicated that about 52 per cent of soils of Odisha are deficient in B, 28 per cent in Zn and 48 per cent in S. Further the soils are low in available N and P but medium in available K [6].B is vital for essential plant functions as it is an integral component which acts as a binding fraction in cell walls and, therefore, supports membrane integrity, cell wall synthesis, and the indole acetic acid mechanism [7]. B has been associated with one or more of the following processes: calcium utilization, cell division, flowering, reproductive phase, water regulation relations, disease resistance, and nitrogen metabolism [8,9]. B deficiency in rice induces panicle sterility due to poor pollen and anther development which reduces the number of grains per panicle and, therefore, grain yield [10,11]. Moreover, B deficiency in rice not only reduces paddy but also damages grain quality [12]. B@1~~kg ha~~kg.ha^{-1} enriched 21% higher pod yield and B uptake of groundnut[13]. Both soil and foliar applied boron have positive effect on growth and yield attributes as well as pod yield of groundnut [14]. An increase in plant height, number of leaves, number of tillers and dry matter accumulation was recorded due to the efficient photosynthetic system, use of NPK and Borax application helped in inducing better vegetative growth [15]. Crop responses to B in acid soils and found that B application increased the yield of cereals by 11.7% and oil seeds by 25.3% [16].Boron application along with soil reclamation by lime enhances nodulation in legumes [17]. Liming also enhances

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nodular properties in different legumes [18] and pulses [19,20].The rice-groundnut cropping system is an important cropping system of the state particularly coastal area and its productivity is declining day by day. Hence Application of B to rice-groundnut cropping system will help increasing the production but the mode and dose of application of limiting nutrient-B in the, coastal district of Odisha has not yet been systematical studies in Jajpur district. The coastal ecosystem of Odisha Hence proper studies to find out the right dose and mode of Boron application for rice-groundnut cropping system necessitates.

2.MATERIALS AND METHODS

A field experiments was conducted under irrigated*Inceptisols*at farmers field of Dihakuransa village,Rasulpur block, Jajpur district of Odisha, India during kharif and rabi seasons of 2016-17 to 2017-18. The experimental site is situated at an altitude of 331 m above sea level and located between $20^{0}30^{'}21.10^{''}$ North latitude and $85^{0}40^{'}86.44^{''}$East longitudes, experiencing warm and humid climate with mean annual rainfall of 1014.5 mm, minimum and maximum temperature of 12^{0}C and 38^{0}C, respectively. The relative humidity varies from64% during winter to 89% during the monsoon.

The experimental soil (0-15 cm) was sandy clay loam with a soil organic carbon content of 5.1 g.kg^{-1}soil. The $KMnO_4$oxidizable N (253.0 kg.ha^{-1}), Bray's-1 P (21.5 kg.ha^{-1}) and NH_4OAc extractable K (129.0 kg.ha^{-1}),$CaCl_2$ extractable S (11.2 mg.kg^{-1}), DTPA extractable Zn (0.72 mg.kg^{-1}), were also studied before the experiment was conducted. The soil. The DTPA extractable Zn was 0.72 mg.kg^{-1}.The hot water extractable B was low 0.24 mg kg^{-1} soil. The experiment was laid out in(RBD) with three replications and eight treatments whose detail is given in Table 1.The test crop ~~were~~was Rice (CVSahabhagidhan (110 days duration) during kharif followed by groundnut (CV- Debi 105 duration) was grown on the same plot. The crop received the soil test dose (STD) over for recommended dose of fertilizer for ~~rice:~~ rice: 80:40:40 kg.ha^{-1}, and groundnut 20:40:40 kg N-P_2O_5-K_2O except through DAP and MOP and urea.Each crop received the B through commercial grade of Borax. as per the treatments.

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Table 1: Treatment Details

Treatments	Rice	Groundnut	Abbreviation
T_1	Control	Control	Control
T_2	STD* (NPK)	STD (NPK)	STD
T_3	STD (NPK) + B@ 1 ~~kgha~~kg.ha^{-1}	STD (NPK) Residual B	R-B1, GN-B0
T_4	STD (NPK)	STD (NPK)+ B @1~~kg ha~~kg.ha^{-1}	R-B0, GN-B1
T_5	STD (NPK) + B@ 0.5 ~~kg ha~~kg.ha^{-1}	STD (NPK) + B @0.5~~kg ha~~kg.ha^{-1}	R-B0.5, GN-B0.5
T_6	STD (NPK)+ B@ 1 ~~kg ha~~kg.ha^{-1}	STD (NPK) + B @1~~kg ha~~kg.ha^{-1}	R-B1, GN-B1
T_7	STD (NPK) + B@ 0.5 ~~kg ha~~kg.ha^{-1}(Basal) B@0.5kg/ha (Tillering)	STD (NPK)+ B @0.5~~kg ha~~kg.ha^{-1}(Basal) B@0.5~~kgha~~kg.ha^{-1}(Flowering)	R-B(0.5+0.5),GN-B(0.5+0.5)
T_8	STD (NPK) + Borax@ 0.25 % (foliar) Tillering Borax@0.25% (PI)	STD (NPK) + Borax@ 0.25 % (foliar) FloweringBorax@0.25% (Pod formation)	R-B(0.25+0.25),GN-B(0.25+0.25)

***Soil Test Dose, B: Boron;**

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2.1 Soil and Plant Sample Analysis

Plant samples of two crops were estimated by using standard procedures.N was estimated by distillation in Kelplus in N estimator [21]. The total P was analyzed by vanadomolybdo-phosphoric acid yellow colour method [22], K was estimated by using flame photometer after diacid digestion [22] and B was estimated by di-acid digestion azomethrin H [23].

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2.2 Nodulation studies

Three plants were randomly from plot area and carefully uprooted with the help of infiltrometer ring for nodule count. The soil cores were watered enough to ease uprooting and to reduce loss of nodules. The roots were then washed in water and nodules counted and dry weights were measured with an electronic balance. Nodulation studies were done at 50 DAS.

2.3 Shelling %

Shelling percentage was calculated by dividing seed weight by dry pod weight and expressed in percentage (%).

$$Shelling\ (\%) = \frac{Seed\ Weight\ (g)}{Pod\ Weight\ (g)}\, x\ 100$$

2.4 Nutrient uptake

The nutrients like N,P,K and Boron uptake in seed and straw/haulm yields were computed by multiplying theirrespective nutrient contents with yields using of following formula:

$$\text{Nutrient uptake in seed}(\text{kg ha}\,\text{kg. ha}^{-1}) = \frac{Concentration\ (\%)}{Seed\ yield\ (\text{q ha}^{-1})}$$

$$\text{Nutrient uptake in straw/haulm}(\text{kg ha}\,\text{kg. ha}^{-1}) = \frac{Concentration\ (\%)}{\text{Straw/Haulm}\ yield\ (\text{q ha}^{-1})}$$

2.5 Oil Content

Oil content was extracted from seeds of groundnut of each plot with the help of Socs plus solvent extractor using acetone as solvent. The % of oil present in a sample was calculated with the help of following formula:

$$\text{Oil content}\ (\%) = \frac{(W2 - W1)}{W} X100$$

Where, W1= Initial weight of beaker

W2=Final weight of beaker (beaker + oil)

W= weight of powdered sample (1g).

2.6 Protein content

Protein content in seed of groundnut was computed by multiplying percent seed nitrogen with a factor of 6.25 [24]**.** The protein yield/ha was calculated by multiplying protein content with corresponding seed yield.

2.7 Reducing Sugar content

Estimation of reducing sugar present in the food stuff was done by Lane and Eynon method [25].

2.8 Non reducing sugar

Non reducing sugar of food stuff was estimated by estimating total sugar and subtracting it by reducing sugar.

2.9 Statistical Analysis

The critical limit of elements in the soil and plants were determined using Cate and Nelson graphical method [26].The field experiment data generated were analyzed statistically as per the analysis of variance technique applicable for randomized block design [27].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data related to growth parameters of the crops has been presented in table 2.Relative growth rate (RGR) of rice and groundnut were positively influenced by application of B RGR at early stage (31-60 DAT) which was more in rice (6.9-7.7 mm day^{-1}) compared to groundnut (4.4 -6.2 mm day^{-1}) at (0-30 DAS) but it was declined towards maturity.The RGR of both the crops were higher when B was applied compared to no B application. Among different doses of B, application of B @ 1kg in two splits was found superior to other mode and dose of application for both the crops. B application to a deficient soil gives positive growth response due to better translocation of photosynthesis further positive effect was observed when applied in splits, the supply of B was continuous under light texture soil [28].

The effective tillers hill^{-1}of rice crop varied from 7.2 to 12.3 in different B applied treatments. The maximum effective tillers were found in T7 which was statistically higher than any other treatments, further it was observed that B application @ 1kg in two split was

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the best.Dose and method of application to light texture acid soil[29].The chaff (%) of rice varied from 15.6-35.2 % in different treatments which was influenced by application of B in different mode and dose.Maximum chaffness(35%) was observed in no B applied plots (control). The chaffness in STD was higher than STD+B, it was more in no B to rice with B to groundnut (T4) compared to its reverse application (T3). The B dose of 1~~kg ha~~kg.ha^{-1} (T6) showed less chaffness compared to 0.5 kg B ha^{-1} (T5). Split application (T7) was better than T6 (once application) and also foliar application. B nutrition has positive effect on fertilization by playing a role in pollen grain germination and elongation of pollen tube. Its application to rice @1~~kg ha~~kg.ha^{-1} in split maintained the B availability in soil to rice plant at reproductive stage, helped better translocation of photosynthates used for filling of grain and reduced chaffness[30].

Nodulation of groundnut was better in plants supplementation with B that is 15.6 % more nodule number compare to no B. Among different method of application more nodule number was observed in higher dose that is 1 kg B ha^{-1} compare to that of 0.5 ~~kg ha~~kg.ha^{-1}. Further split application of B was superior to once application.B is needed for development of nodules. Groundnut being a root nodulating oil seed crop was benefited for atmospheric N_2 fixation and supplementation to the host plant groundnut [31-33].

3.2Economic Yield of rice-groundnut cropping system.

The rice grain yield influenced considerably by B nutrition 14% and varied between 2.82 t ha^{-1} to 4.19 t ha^{-1}(Table 3).Boron application @1~~kg ha~~kg.ha^{-1} to the 1st crop (rice) had significant influenced (15.3%) on grain yield than to the 2nd crop(groundnut).Split application of Boron tillering and panicle initiation stage @0.5 kg B ha-1 to each crop had significant influence on the grain yield of rice (9.4%) higher and 3.0 %higher than full dose without split and was superior to its foliar application by 11.5%. Similarly, groundnut crop responded significantly to B application by increasing pod yield significantly (22.7 %) over its non-application. The pod yield varied considerably between 1.35t ha^{-1} and 2.2 t ha^{-1} lowest with control and highest where B was applied in split[34].

Rice equivalent yield (REY)

The rice equivalent yield of rice-groundnut cropping system varied significantly between 7.19 t ha^{-1} to 11.4 t ha^{-1}, highestwith split application of B and lowest with control. B application increased the REY of the cropping system by 19.5% than no B.The system yield in the form of REY varied significantly to B supplementation. Split application of full dose was found superior to the foliar application by 15%, further it was 5.6% more than its once application. The crop which received B nutrition first had exhibited its influence on economic productivity, reason being bare necessity of B in crop growth process, transport of photosynthates, water and nutrients (inputs for photosynthetic activity), keeping pollens viable and active leading towards better fertilization converting to grain/pod yield. Mode of B supplementation had considerable and profound influence on economic yields. Soil application of B in split doses at active growth stages of both crops could meet higher requirement for physiological and reproductivity activities. In terms of REY of the system such mode of B supplementation-maintained RAE of 288 against 186 due to foliar application[35].

3.3 Uptake and recovery of N, P, K and B.

The data related to nutrient uptake, and recovery in the rice-groundnut cropping system has been presented in table 4.

Nitrogen

The total uptake of N by rice varied from 67.6 kg.ha^{-1} to 109 ~~kg ha~~kg.ha^{-1} and groundnut varied from 67.7 ~~kg ha~~kg.ha^{-1}to147.8 ~~kg ha~~kg.ha^{-1}. The uptake of N by groundnut was more than rice crop due to higher concentration of N in groundnut. The reason is groundnut behaves like pulse crop in nodulation and subsequent N fixation. B supplementation triggered the nodulation resulting with high N fixation and more assimilation by the groundnut crop than rice. B supplementation irrespective of method application enhanced 25.5 % N uptake over no B. B application to either of the crop had no significant change in N uptake of the system. Full dose basal application to each crop was better than its half rate indicating the former dose being optimum in the light texture soil. Split application of full dose to soil proved superior to its ones application due to continuous supply of B throughout the growth period. Further split application of full dose performed better than the foliar spray because applied B to soil helped for better N fixation compare to foliar B [36]. The recovery of applied nitrogen in the cropping system varied between 23.0 and 60.8 percent, lowest with no Boron application practice STD and highest with split application practice.Apparent nitrogen recovery(ANR) was enhanced by B over no B application.Split application helped the better ANR of rice-groundnut system.

Phosphorus

The rice crop removed more phosphorus (ranging from 13.3 to 35.7 kg P ha^{-1}) than the groundnut crop (ranging from 9.6 to 23.2~~kg ha~~kg.ha^{-1}). B application enhanced P uptake by 36.4% over its non-application in the system. Full dose of B increases P uptake by 18.3% compare to half dose. Split application accounted 27% more P uptake over foliar spray.

Apparent phosphorus recovery (APR) followed the same trend as total P uptake. The APR of 19.8% due to non-supplementation of deficient nutrient B, ~~It~~it could be raised to a range of 32.8 to 51.0% level with its supplementation and highest with split application[37,38].

Potassium

The Rice crop removed more potassium ranging from 26.8 to 61.4 kg K ha^{-1}than groundnut crop ranging from 20.3 to 58.0 kg K ha^{-1}. Due to different B supplementation. Either rice or groundnut could not influence K uptake for the system but full dose B application to both crops was better than its half rate. Splitting the full dose was found better than its one's application or foliar spray. The apparent potassium recovery (AKR) ranged between 15.1% to 54.4%. B application played a vital role for K recovery by the crops [35].

Boron

The data related to B nutrition in rice-groundnut cropping system have been presented in Table 3.The crops received B@ 2000 g in treatment no 3,4 and 5, where as in treatment no 6 and 7 it was 4000 g each in two years. In foliar practice there was altogether 952 g application of boron. In rice-groundnut cropping system, rice crop removed more Boron (ranging from 115 to 411.2 g ha-1) than groundnut crop (ranging from 94.8 to 321.6 g ha^{-1}). The total B uptake varied widely between 209.7 g ha^{-1} and 732.8 g ha^{-1}.

Rice crop removed more B than groundnut. Groundnut crop content more B than rice. It was simple exhibit of genetical ~~behaviour~~behavior of two crops. Supplementation of B increase the uptake by 55.4 % over no application conforming the B need by the cropping system in a light texture acid soil. Its application to either crop in the system had not significant influence on the uptake by the system. Application@ 1~~kg ha~~kg.ha^{-1} proved better than half rates for B uptake and recovery by the system, indicating 0.5 ~~kg ha~~kg.ha-1 was sub optimal dose for rice-groundnut cropping system. 1 kg B application in two splits, found superior to 1kg application of one time as basal. Confirming the continuous B availability throughout the growth period is more important than its shortage towards the reproductively stage. Split application to soil was found better than twice foliar spray. It's indicated the role of B in soil is multipherous (both soil and plant) compare to foliar application B, only plant). The uptake of B in groundnut crop [39].

Right method and dose of B helped in better optimizing balanced fertilization approaches which created neither deficiency nor excess of nutrients creating positive interaction among all essential nutrients which was manifested in the form of better nutrient recovery.

3.4Crop quality:

The data related to crop quality have been presented in table 5.

Thousand grain weight of rice:

Thousand grain weight of rice under influence of B application varied from 21.2 to 23.9 g, lowest with no B (control) and highest with split application. Split application proved superior than other treatments. B nutrition influenced the grain weight by 4% compared over 22.4g due to lone STD practice. Crop receiving B application irrespective of the doses increased thousand grain weight, the higher rate of its application compared to the lower dose. Among two methods of application, the split application method proved superior to foliar spray by 3.9%.The B helped in sugar/photosynthate translocation, grain filling and high-test weight[40].

Protein content

Protein content of rice grain ranged between (9.2% to 10.5 %), and in groundnutkernel varied from (27.2% to 35.9%), lowest with control and highest with split method of application. B supplementation helped in increasing protein content ofboth crops as compared to no application conforming the indirect role of B in protein synthesis. Application of B @1~~kg ha~~kg.ha^{-1}in both crops found significantly influence in protein content for both crops compared to its half doses. Spliting the soil application of 1~~kg ha~~kg.ha^{-1} produced more protein in crop compared two once soil and foliar application. The biological protein synthesis in crops is influenced by presence of B. Hence optimum B concentration in plant during its growth period is regulated by different method. Split application of 1 kg B ha^{-1} at two critical growth stages was found must appropriate dose and time of application [41].

Kernel weight and shelling per cent

The 100-kernel weight of groundnut varied considerably between 36.1 and 42.4 g. which constituted the shelling per cent varying between 58.2% to 64.1%. Boron supplementation had considerable influence on these two parameters, being 8.5% and 4.5% respectively compared over no B supplementation. Groundnut crop receiving full dose of B (@1~~kg ha~~kg.ha-1), rather than residual B (of rice), higher rate of B application (1kg Beach crop) and soil application in split methods had advantage of higher kernel weight with higher shelling per cent [42].

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Oil content:

There was considerable influence of B management in rice-groundnut cropping system.The oil content in groundnut kernel varied between 46.4% to 49.8%, lowest with no B(control) and highest with split method. Oil is the most economical part of groundnut crop;

it was influenced by B application by 3.2% over no application.Application @1kg B ha^{-1} was found superior to 0.5 kg B ha^{-1}. Split application of 1kg B ha^{-1}was found superior to its once application or its foliar spray because availability of B to groundnut crop during oil synthesis process accounts a lot [31].

Sugar content in kernel

Considerable variations were observed in both the types of sugar content in groundnut kernel (Table 4). The reducing sugar content was less (ranging from 1.8 to 3.5%) than the reducing sugar (ranging from 14.2 to 16.5%).

Both reducing and nonreducing sugar contain increase with application of B in groundnut. B application to groundnut crop produced more sugar compare to residual B. Higher dose@ 1~~kg ha~~kg.ha^{-1} produced more sugar than 0.5 ~~kg ha~~kg.ha^{-1}. Further 1kg B ha^{-1} split application produced more sugar than 1kg B once application to soil or foliar spray, confirming the role of B in sugar synthesis and translocation in groundnut [43].

Conclusion

Both rice and groundnut crops responded significantly to external supplementation of inputs specifically the limiting nutrient B. Growth of rice crop was influenced by 4.1% and groundnut crop by 9.7% due to supplementation of B. Its supplementation increased the effective tiller number by 24.4%, 4% higher 1000 grain weight and reduction in chaffness by 40%. Soil application of B in split doses at the active growth stages of both crops proved to be efficient with respect to effective tiller number, in reducing chaffiness from 18% level to 15% level and increased the test weight by 4% compared to the spray method of its application. Nodulation of groundnut crop was influenced by 16% by B supplementation from external source. Both dose of B and its direct receipt by groundnut crop by split soil application proved to improve nodulation behavior. The economic productivity of rice crop varied between 2.82 and 4.19 t ha^{-1} and groundnut crop between 1.35 and 2.22 t ha^{-1} and their REY between 7.19 and 11.4 t ha^{-1} under the influence of B management practices. Supplementation of limiting nutrient B in the cropping system influenced the productivity by 19.5% compared over no supplementation. Full dose of application of B @ 1 kg B ha^{-1} had the advantage of 8.7 % higher than the half rate. Soil application of B in split method at active growth stages had benefited the productivity by 15% than spray application method. Such practice recorded the RAE of 288 compared to 186 due to spray method.Supplementation of growth limiting nutrient B could double the apparent recovery of N (46% with B against 23% without B) and P (38.8% with B against 19.8% without B). The apparent K recovery could be raised to 40.6% against only 15.1% without B supplementation.

Such practice helped recovery of B on an average by 18.2%. Soil application of B to each crop in split doses could raise the recovery of N, P and K to the extent of 60.8%, 51%, and 54.4% respectively but recovery of B was registered only at 13.1%. Supplementation of B influenced protein content of rice and groundnut crop by 6.2% and 8.2% over the contents of 9.4% and 30.8%protein content due to soil test dose of N, P, and K, without B supplementation. Boron supplementation improved oil content of groundnut by 3.2% achieving 49.8%level, so also the reducing and non-reducing sugar contents of 3.5% and 16.5% respectively.

Table- 2.Growth parameters

Sl.No	B-management practices	Rice				Groundnut			Rice		Groundnut
		Average relative growth rate (mm day^{-1})							Number of effective tillers/hill	Chaff (%)	Nodule number/plant
		0-30	31-60	61-90	91-110	0-30	31-60	61-105			
		Days After Transplanting				Days After Sowing					
1	Control	6.4	7.3	6.6	1.3	4.4	4.0	3.2	7.2	35.2	78
2	STD	7.0	7.3	6.6	1.3	5.0	4.1	3.3	9.1	30.3	92
3	R-B1,GN-B0	8.7	6.9	6.0	1.8	5.4	4.0	3.5	11.3	17.1	95
4	R-B0,GN-B1	7.2	7.4	6.5	1.6	5.7	4.4	3.6	10.1	26.2	107
5	R-B0.5,GN-B0.5	8.3	7.6	5.6	2.4	5.5	4.2	3.6	11.3	18.1	102
6	R-B1,GN-B1	8.9	7.7	5.5	2.7	6.0	4.4	3.5	12.2	16.4	114
7	R-B(0.5 +0.5), GN-B(0.5+0.5)	9.0	7.7	6.3	1.4	6.2	4.7	3.3	12.3	15.6	115
8	R-B(0.25+0.25), GN-B(0.25+0.25	8.0	7.3	6.0	2.3	5.7	4.3	3.6	11.3	18.2	105
	LSD (p=0.05)				4.29			5.2	0.59	1.92	6.2

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Table 3 Economic productivity of rice-groundnut cropping system and REY of B management practices Pool data of 2016-17 and 2017-18 of both crops

Sl.No	B-management practices	Productivity (t ha^{-1})			RAE (%)
		Rice*	Groundnut*	REY	
1	Control	2.82	1.35	7.19	-
2	STD	3.37	1.63	8.65	100
3	R-B_1,GN-B_0	3.93	1.84	9.91	186
4	R-B_0,GN-B_1	3.41	2.06	10.10	199
5	R-$B_{0.5}$,GN-$B_{0.5}$	3.83	1.88	9.94	188
6	R-B_1,GN-B_1	4.07	2.09	10.8	250
7	R-B(0.5 +0.5), GN-B(0.5+0.5)	4.19	2.22	11.4	288
8	R-B(0.25+0.25), GN-B(0.25+0.25)	3.71	1.91	9.91	186
	LSD(p=0.05)	0.20	0.16	0.74	-
	CV(%)	11.0	9.0	9.0	-

Table 4. Uptake and recovery of N, P, K and B under variable B fertilization in rice-groundnut cropping system.

SlNo	B-management practices	Added N	N Uptake (~~kg ha~~kg.ha^{-1})			ANR (%)	Added P	P Uptake (~~kg ha~~kg.ha^{-1})			APR (%)	Added K	KUptake (~~kg ha~~kg.ha^{-1})			AKR (%)	Added B	B Uptake (g ha^{-1})			ABR (%)
		(kgha^{-1})	Rice	G.nut	Total		(kgha^{-1})	Rice	G.nut	Total		(kgha^{-1})	Rice	G.nut	Total		(g ha^{-1})	Rice	G.nut	Total	
1	**Control**	0	67.6	67.7	135.3	-	0	13.3	9.6	23.0	-	0	26.8	20.3	47.1	-	0	115	94.8	209.7	-
2	**STD**	200	88.3	92.9	181.2	23.0	70	21.7	15.2	36.8	19.8	133	40.0	28.2	68.2	15.1	0	201.1	180.4	381.5	-
3	**R-B_1,GN-B_0**	200	108.8	110.9	219.7	42.2	70	28.8	17.6	46.4	33.4	133	55.1	39.6	94.6	35.3	2000	350.3	225.8	576.1	18.3
4	**R-B_0,GN-B_1**	200	82.0	127.3	209.3	37.0	70	22.8	23.2	46.0	32.8	133	41.8	53.6	95.4	36.3	2000	219.3	274.1	493.4	14.2
5	**R-$B_{0.5}$,GN-$B_{0.5}$**	200	92.0	114.0	206.0	35.4	70	29.0	18.5	47.5	35.0	133	52.10	38.7	90.8	32.9	2000	309.3	248.1	557.3	17.4
6	**R-B_1,GN-B_1**	200	104.0	138.2	242.2	53.5	70	33.3	22.0	56.2	47.4	133	57.6	55.9	113.5	49.9	4000	375.8	279.1	654.9	11.1
7	**R-B(0.5 +0.5), GN-B(0.5+0.5)**	200	109.0	147.8	256.8	60.8	70	35.7	23.0	58.7	51.0	133	61.4	58.0	119.4	54.4	4000	411.2	321.6	732.8	13.1
8	**R-B(0.25+0.25), GN-B(0.25+0.25)**	200	102.4	127.6	230.0	47.4	70	26.9	19.3	46.2	33.1	133	47.5	45.8	93.3	34.7	952	283.9	258.0	541.9	34.9
	LSD(p=0.05)		17.55	20.5	26.6			4.75	3.98	6.13			8.39	10.20	9.33			55.36	50.94	89.5	
	CV(%)		9.0	11.0	8.0			10.0	11.0	8.0			10.0	12.0	6.0			11.0	12.0	9.0	

Table 5 Effect of B on crop quality of rice and groundnut

Si.No	B-management practices	Rice		Groundnut					
		1000 grain weight (g)	Protein Content (%)	100 kernel weight (g)	Protein Content (%)	Oil content (%)	Reducing sugar content (%)	Non-reducing sugar content (%)	Shelling (%)
1	Control	21.2	9.2	36.1	27.2	46.4	1.8	14.2	58.2
2	STD	22.4	9.4	38.2	30.8	47.2	2.2	14.5	60.6
3	R-B1,GN-B0	23.4	10.0	40.6	31.8	47.7	2.6	14.7	63.2
4	R-B0,GN-B1	22.5	9.4	41.9	33.0	49.0	3.4	15.8	63.9
5	R-B0.5,GN-B0.5	23.0	10.0	40.5	32.3	48.3	3.0	15.5	62.3
6	R-B1,GN-B1	23.8	10.2	42.4	34.4	49.2	3.5	16.4	64.1
7	R-B(0.5 +0.5), GN-B(0.5+0.5)	23.9	10.5	42.1	35.9	49.8	3.5	16.5	63.5
8	R-B(0.25+0.25), GN-B(0.25+0.25)	23.0	9.8	41.1	32.8	48.2	3.3	15.5	63.1
	LSD(p=0.05)	0.76	0.62	0.89	2.13	1.04	0.54	0.33	0.91
	CV(%)	5.2	4.5	8.2	8.5	9.2	11.0	7.6	11.3

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Comment [A10]: The sources are outdated. They need to be updated.

Comment [A11]: Author guide

Comment [A12]: Author guide

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