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Relationship of physiological attributes and nitrogen with yield of direct seeded rice and brahmi

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Abstract
An experiment was conducted during the *kharif* seasons of 2015 and 2016 at Norman E. Borlaug Crop Research Centre, G.B. P.U.A&T, Pantnagar, Uttarakhand to to study the physiological parameters and nitrogen uptake on yield and economics of direct seeded rice and brahmi intercropping system and also best weed management practice for the system as a whole. The result revealed that the all the growth parameter were found significantly higher in sole rice (pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS) which was found at par with paired (2:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS while in brahmi crop, sole brahmi (3 hand weedings at 30, 45 and 60 DAP) treatment recorded significantly higher value of growth parameters. Maximum nitrogen content and uptake were recorded in sole rice (pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS) and sole brahmi (3 hand weedings at 30, 45 and 60 DAP) treatment in crop rice and brahmi. Highest rice grain yield was found in sole rice (pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS) and highest brahmi dry herb yield in sole brahmi (3 hand weedings at 30, 45 and 60 DAP). Maximum net returns and benefit cost ratio were recorded in alternate (1:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS.

Keywords: Direct seeded rice, brahmi, intercropping, growth, nitrogen, yield, economics

1. Introduction
Rice (*Oryza sativa* L.) is the most important cereal food crop of the developing world and the staple food of more than 3 billion people or more than half of the world's population (Singh *et al.* 2014) [9]. One fifth of the world's population more than a billion people depend on rice cultivation for their livelihoods. Traditional crop establishment methods in rice-wheat system such as puddle transplanted rice and conventional till (CT) wheat require large amount of water, energy and labour, which are becoming increasingly scarce and expensive. Change in rice establishment method from traditional transplanting system to direct-seeding has occurred in Asian rice systems in the last two decades in response to economic factors and technological opportunities in farming (Chauhan and Johnson, 2010)[2]. Weed infestation, however continues to be a major bottleneck in dry seeded rice because of simultaneous emergence of rice and weeds and absence of standing water at the early stages of crop to suppress weed growth (Farooq *et al.*, 2011) [4]. Brahmi is one of the medicinal plants which can be grown like rice in upland as well as in lowland conditions and the crop will be ready after 90 days of transplanting and can continue for a longer period as per availability of water.
The leaf area/hill or leaf area/spread material and leaf area index are the main growth factor which may directly reflect to grain yield. Growth analysis parameters like crop growth rate (CGR) are product of LAI. Relative growth rate (RGR) measures the increase in dry matter with a given amount of assimilatory material at a given point of time**.** Considering these facts in the present investigation, two row combinations were taken with different weed management practices in rice + brahmi to find out the feasible and profitable intercropping system.

Materials and methods
The experiment comprises on 10 treatment combinations was conducted at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Distt. Udham Singh Nagar (Uttarakhand) during *kharif* seasons of 2015 and 2016.

This centre is situated at an altitude of 243.84 m above sea level, 29^0N latitude and 79.3^0E longitudes. The research centre falls under foothills of Shivalik ranges of Himalaya, a narrow belt called "*tarai* belt" of Uttarakhand state. The objective of study was to study the physiological parameters and nitrogen uptake on yield and economics of direct seeded rice and brahmi intercropping system. The soil of the experimental field was loam in texture. The experimental plot was medium in organic carbon (0.86 and 0.86%), medium in available phosphorus (22.8 and 19.8%) and available potassium (145.4 and 145.4%), low in available nitrogen (226.2 and 223.4%) with neutral pH (7.3) during both the years. The experiment was laid out in Randomized Block Design by taking ten treatments with three replications *i.e.* two ratios 1:1 *i.e.* direct seeded rice and brahmi in additive series (where brahmi crop was sown at the spacing of 40 cm and one row of rice was sandwitched between two rows of brahmi at 20 cm) and 2:1 *i.e.* direct seeded rice and brahmi in replacement series (where brahmi crop was sown at the spacing of 20 cm after two rows of rice at 20 cm) and with both row ratios, four different weed management practices were taken *i.e.* (pendimethalin 1 kg/ha + 2 hand weedings (H.W.), pendimethalin 1 kg/ha and pendimethalin 1 kg/ha + cyhalofop-butyl 20 g/ha + 1 hand weeding) and one treatment of sole rice and sole brahmi. Furrows were opened manually with the help of liners at a specified row to row distance of 20 cm. The rice variety "Pant-18" was sown on June 9, 2015 and June 7, 2016 and brahmi variety "CIM Jagriti" was sown on June 10, 2015 and June 8, 2016 using a seed rate of 17 kg/ha and 3.3 t/ha in additive series and 21 kg/ha and 2.5 t/ha in replacement series, respectively. All the herbicides were sprayed using knap sack sprayer fitted with flat fan nozzle. The recommended fertilizer doses of rice (120:60:40) were applied uniformly through NPK (12:32:16) mixture and rest through Urea and Muriate of potash and the irrigation was given accordingly. Weedy check plots remained infested with native population of weeds till harvest. Observations on weeds were recorded with the help of quadrate 0.5 x 0.5 m^2 placed randomly at two spots in each plot at 60 days after sowing/planting (DAS/DAP). Weed population and weed dry weight were recorded at 60 days after sowing.

Plant observation such as LAI, CGR, RGR, leaf area/ hill or leaf area/spread material were recorded at 60 and 90 DAS/DAP. To calculate CGR (Crop growth rate) and RGR (Relative growth rate) following formula were used:

$$\text{CGR (g/ day/hill)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are dry matter production at times t_1 and t_2 respectively.

$$\text{RGR (g/ g /day)} = \frac{\text{In } W_1 - \text{In } W_2}{t_1 - t_2}$$

Where,

In W_1 and In W_2 are the natural logarithm of total dry weight of plant/ hill at time t_1 and t_2 respectively.

and LAI (Leaf area index) was calculated with the help of instrument "Ceptometer".

Results and discussion

Effect on growth analysis

All the growth parameters were found to be significantly influenced due to various intercropping and weed management practices in direct seeded rice (DSR) and brahmi intercropping system during both years (Table 1). Crop growth rate (CGR), relative growth rate (RGR), leaf area index (LAI) and leaf area, was significantly higher in sole rice (pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS) treatment which was at par with paired (2:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS except leaf area index in direct seeded rice crop during both the years. Crop growth rate increased slowly at early stages of growth and reached the peak at booting to heading stage, thereafter, it declined. This was due to the maximum production of dry matter at early stages of plant growth and it represents the net result of photosynthesis, respiration and canopy area interception (Alam, 2013) [1]. The variation in LAI was an important physiological parameter that eventually determines ultimate crop yield because it influences the light interception by the crop canopy (Fageria *et al*., 2006) [3].

In brahmi crop, CGR, RGR, leaf area index (LAI) and leaf area/spread material was significantly higher in sole brahmi (3 hand weedings at 30, 45 and 60 DAP) treatment followed by alternate (1:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS during both the years. Rajput *et al*. (2017)[7] reported that LAI increased orderly up to growth stage, and then declined slowly up to harvest under subtropical climatic condition.in brahmi.

Effect on nitrogen content and uptake

Nitrogen content and uptake was significantly influenced in DSR and brahmi crop by different intercropping and weed management practices in DSR and brahmi intercropping system during both the years. Maximum nitrogen content and uptake in rice grain was recorded in sole rice (pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS) followed by paired (2:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS during both the years (Table 1). Kiran *et al*. (2015) [5] reported significantly higher grain and straw nitrogen concentration (1.45%) in direct seeded rice compared to that of transplanted rice (1.08%).

Maximum nitrogen content and uptake in brahmi was recorded in sole brahmi (3 hand weedings at 30, 45 and 60 DAP) treatment followed by alternate (1:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS during both the years.

Table 1: Effect of different weed control treatments on growth parameters of rice and brahmi in direct seeded + brahmi intercropping system (Pooled data of 2 years)

Treatments	Rice								Brahmi							
	Crop growth rate		Relative growth rate		Leaf area index		Leaf area (cm^2/hill)		Crop growth rate		Relative growth rate		Leaf area index		Leaf area/spread material (cm^2)	
	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
1:1Pendi (PE)	0.38	0.88	2.70	3.65	7.1	7.7	1578.00	2066.00	3.63	3.94	1.3	1.36	0.15	0.20	238.96	263.96
1:1 Pendi (PE)+2 HW (30 and 45 DAS)	0.39	1.07	2.73	3.80	7.9	8.4	1680.00	2118.00	4.60	4.80	1.51	1.54	0.17	0.23	248.96	278.96
1:1 Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	0.45	1.18	2.86	3.91	8.4	9.6	1902.00	2289.98	5.27	5.33	1.64	1.65	0.19	0.25	260.96	289.96
1:1 Weedy	0.40	0.75	2.67	3.53	4.2	4.5	1022.00	1210.00	2.80	2.96	1.03	1.08	0.13	0.15	129.98	160.00
2:1Pendi (PE)	0.40	0.98	2.74	3.73	7.9	8.2	1680.00	2168.00	3.03	3.30	1.11	1.19	0.14	0.18	235.93	255.96
2:1 Pendi (PE)+2 HW (30 and 45 DAS)	0.42	1.15	2.83	3.86	8.3	9.4	1768.00	2280.00	4.50	4.62	1.5	1.51	0.16	0.21	242.00	269.00
2:1 Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	0.44	1.30	2.89	3.97	8.7	10.3	1850.00	2358.00	5.03	5.19	1.6	1.62	0.17	0.24	257.96	283.00
2:1 Weedy	0.40	0.80	2.70	3.56	4.4	5.2	1190.00	1280.00	2.53	2.90	0.93	1.07	0.11	0.14	125.00	153.96
Sole rice Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	0.46	1.40	2.94	4.03	9.2	11.2	2015.00	2409.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sole brahmi (30, 45&60 DAS)	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	5.54	5.63	1.70	1.70	0.20	0.26	269.96	309.96
SEm±	0.007	0.02	0.02	0.05	0.13	0.12	17.57	28.33	0.04	0.06	0.015	0.016	0.003	0.003	2.36	3.34
CD (p=0.05)	0.022	0.5	0.07	0.17	0.38	0.37	52.22	84.20	0.13	0.17	0.045	0.050	0.01	0.009	6.96	9.94

Where, DSR-Direct seeded rice, Pendi - Pendimethalin, Cyhalo- Cyhalofop-butyl, H.W.-Hand weeding, PE- Pre-emergence, PoE – Post-emergence, DAS – Days after sowing, DAP- Days after planting, fb-followed by

Table 2: Effect of different weed control treatments on nitrogen content and uptake in rice grain and brahmi and yield of rice and brahmi and economics of direct seeded rice and brahmi intercropping system (Pooled data of 2 years)

Treatments	Nitrogen in rice grain		Nitrogen in brahmi		Grain yield (t/ha)	Harvest index (%)	Production efficiency (%)	Brahmi dry herb yield (t/ha)	Net returns (`/ha)	Benefit cost ratio
	Content (%)	Uptake (kg/ha)	Content (%)	Uptake (kg/ha)						
1:1Pendi (PE)	1.46	46.72	0.87	14.964	3.2	26.77	3.41	1.49	216205.6	8.58
1:1 Pendi (PE)+2 HW (30 and 45 DAS)	1.47	52.92	0.88	16.28	3.61	36.80	4.78	1.82	232306.6	7.24
1:1 Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	1.48	62.16	0.89	17.8	4.20	44.68	5.36	1.94	269586.14	9.41
1:1 Weedy	1.40	0.00	0.85	3.4	0.0	0.00	3.02	0.92	172795.6	0.73
2:1Pendi (PE)	1.46	56.94	0.87	6.96	3.90	31.17	4.07	0.67	145795.6	5.80
2:1 Pendi (PE)+2 HW (30 and 45 DAS)	1.48	63.64	0.89	10.68	4.30	42.57	4.95	1.08	174135.6	5.42
2:1 Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	1.49	71.52	0.91	11.83	4.81	47.62	5.52	1.25	192987.1	6.74
2:1 Weedy	1.41	4.23	0.86	4.3	0.3	32.25	3.06	0.76	34212.0	1.45
Sole rice Pendi (PE)+Cyhalo (PoE) +1 H.W. (45 DAS)	1.51	80.03	0	0	5.30	35.07	5.82	0.17	85336.1	2.98
Sole brahmi (30, 45&60 DAS)	0.00	0.00	0.93	19.251	0.00	0.00	0.00	1.40	177212.6	5.22
SEm±	0.01	0.54	0.01	0.18	0.06	0.45	0.07	0.32	-	-
CD (p=0.05)	0.03	1.60	0.04	0.54	0.17	1.35	0.21	0.97	-	-

Where, DSR-Direct seeded rice, Pendi - Pendimethalin, Cyhalo- Cyhalofop-butyl, H.W.-Hand weeding, PE- Pre-emergence, PoE – Post-emergence, DAS – Days after sowing, DAP- Days after planting, fb-followed by

Effect on rice and brahmi yield and economics

Sole stand of rice recorded significantly higher grain yield and production efficiency which was followed by replacement series in both paired (2:1) and alternate (1:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS which in turn also differed significantly from one another in rice + brahmi intercropping system during both the year of experimentation. This result might be due to less competition for sunlight, space, water and nutrients for sole crop as compared to intercropping treatments (Table 2). However, between additive and replacement treatments, significantly higher grain yield of brahmi under additive series might have happened mainly due to significantly higher plant population as compared to replacement series. Tripathi *et al.* (2005) [10] also realized similar results for grain yield for chickpea in chickpea + mustard intercropping system.

Brahmi in sole stand recorded significantly higher herbage yield (Table 2) and was followed by additive and replacement series which in turn differed significantly from one another in rice + brahmi intercropping system during both years. Maximum herbage yield among intercropping treatments was recorded with the application of pendimethalin fb cyhalofop -

butyl fb one hand weeding at 45 days after sowing/planting in both row ratios *i.e*. 1:1 and 2:1 which was followed by treatment pendimethalin fb two hand weedings at 30 and 45 days after sowing/planting. The optimum space as available for brahmi plants under sole stand reduced the competition for moisture, nutrients and light among the brahmi plants as compared to that as provided under other intercropping combinations might be responsible for the production of higher yield attributes of sole crop of brahmi. These results are in agreement with the findings of Singh *et al*. (2008) [8].

During both the years, the intercropping patterns affected the net returns and benefit cost ratio. The highest net returns and benefit cost ratio was found in the treatment pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS in alternate (1:1) ratio of rice and brahmi during both the years of experimentation (Table 2). Matusso *et al*. (2014) [6] reported that maize + cowpea intercropping was more profitable than their sole crops. These results suggest that intercropping could improve the system's productivity, increase the income for smallholder farmers, and compensate losses.

Conclusion

From the above study, it can be concluded that best treatment combination is alternate (1:1) ratio along with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS/DAP with respect to benefit cost ratio which is main objective of the study followed by paired (2:1) ratio, combination with pendimethalin fb cyhalofop-butyl fb one hand weeding at 45 DAS/DAP.

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