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Article

Effect of Biopower Application on Weed Growth and Yield of Rice

Efeito da Aplicação do Biopoder no Crescimento de Plantas Daninhas e na Produção de Arroz

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ABSTRACT - Biopower is a commercial rice biofertilizer comprised of various associative nitrogen fixers. In this present study, a field trial was carried out to assess the effects of Biopower application on the growth of some rice weeds and yield of rice (*Oryza sativa*). Four common rice weeds namely *Cyperus rotundus, Echinochloa colonum*, *Marsilea minuta, Paspalum paspaloides,* and mixed weeds were sown in 1:1 weed crop ratio in soil amended with i) ½ dose of N (nitrogen) + recommended doses of PK (phosphorus, potassium) fertilizers, ii) recommended doses of NPK fertilizers, and iii) farmyard manure (FYM) + ¼NPK fertilizers, with and without Biopower application. Biopower application variably reduced weed biomass in different soil amendment systems. The effect of Biopower on weed biomass was most pronounced in NPK, followed by FYM amendment, resulting in up to 50% and 36% reduction in weed biomass, respectively. Biopower application enhanced shoot N content of rice in all the treatments. The effect of Biopower application on shoot N content was most pronounced in ½N-PK and least in NPK applied plots. The four weeds planted with rice reduced rice grain yield by 12-75% in different soil amendments. Biopower application enhanced grain yield in rice, in weed free control, and in different weeds infested plots by 38-90% in ½N-PK, 6-13% in NPK and 12-150% in FYM applied plots. The present study has come to the conclusion that adverse effect of weeds on grain yield of rice can be managed by the application of Biopower in combination with either ½N-PK or FYM amendment.

Keywords: associative nitrogen fixers, biofertilizer, weed suppression.

RESUMO - Biopower é um biofertilizante comercial para arroz composto de vários fixadores de nitrogênio associativos. Neste estudo, realizou-se um ensaio de campo para avaliar o efeito da aplicação de Biopower no crescimento de algumas plantas daninhas de arroz e na produção de arroz ***(Oryza sativa****). Foram semeadas quatro espécies de plantas daninhas comuns:* ***Cyperus rotundus****,* ***Echinochloa colonum****,* ***Marsilea minuta*** *e* ***Paspalum paspaloides****; plantas daninhas variadas foram semeadas na proporção de 1:1 em solo ajustado com i) meia dose de N (nitrogênio) + doses recomendadas de adubos PK (fósforo, potássio), ii) doses recomendadas de adubos NPK e iii) estrume de quintal + fertilizantes NPK, com e sem aplicação de Biopower. A aplicação desse biofertilizante reduziu de forma variável a biomassa de plantas daninhas em diferentes sistemas de ajuste do solo. O efeito do Biopower na biomassa de plantas daninhas foi maior em NPK, seguido por ajuste de FYM (esterco da fazenda), resultando em redução de até 50% e 36% na biomassa de plantas daninhas, respectivamente. A aplicação do Biopower aumentou o teor de N no arroz em todos os tratamentos. O efeito da aplicação do biofertilizante no teor de N da parte aérea foi mais acentuado em ½N-PK e menor nas parcelas onde*

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houve aplicação de NPK. As quatro plantas daninhas plantadas com arroz reduziram o rendimento de grãos de arroz em 12-75%, em diferentes ajustes do solo. A aplicação de Biopower aumentou o rendimento de grãos de arroz no controle, livre de plantas daninhas, e em diferentes parcelas infestadas por plantas daninhas em 38-90% em ½N-PK, 6-13% em NPK e 12-150% em parcelas com FYM. O presente estudo concluiu que o efeito adverso das plantas daninhas na produção de grãos de arroz pode ser combatido com a aplicação de Biopower juntamente com ajustes de ½N-PK ou de FYM.

Palavras-chave: fixadores de nitrogênio associativos, biofertilizante, supressão de plantas daninhas.

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important agricultural commodities consumed by half of the world population (Klipp et al., 2004). Globally, rice ranked 3rd on production basis, after sugarcane and maize, and it grows on 162.3 million hectares with 738.1 million tones production (FAOSTAT, 2012). Pakistan is the 11th largest producer of rice, cultivated on 2891 thousand hectares with 7003 thousand tones of production (Pakistan Bureau of Statistics, 2015). Punjab and Sindh are the leading provinces, contributing with 88% of total rice production (Memon, 2013). Export of rice has declined in the last few years, due to reduced area for cultivation and less production (Memon, 2013). Among several factors contributing with such low yield of rice crop, weeds are a potential threat to rice production, responsible for significant yield loss annually (Rabbani et al., 2011). Several herbicides are available in the market to fight weed infestation in rice field (Khaliq et al., 2012). However, unselective use of herbicides has resulted in resistant weeds along with environmental degradation (Bari, 2010). Therefore, alternative environmental friendly strategies are needed immediately against weed infestation in rice fields.

Nitrogen is a major nutrient needed for plant growth and its deficiency in Pakistani soil is an important factor to be considered (Rashid, 1994). Modern rice varieties demand more N over conventional ones, therefore, generally N responsive crop species are known to compete better under high N fertilization, but N application equally benefit weeds (Ehsanullah et al., 2001; Begum et al., 2009). Several studies have shown positive effects of incorporation of adequate nitrogen fertilizer on plant growth and yield, and vice versa, on weeds (Abbas et al., 2003; Rozas et al., 2008; Khan et al., 2012). Ehsanullah et al. (2001) reported that hoeing the crop twice followed by transplanting with high dose of fertilizers (N: 100 kg and P: 80 kg) proved very effective in enhancing grain yield of rice by controlling weeds. Bado et al. (2011) showed the best weed control in rice with optimum doses of recommended N fertilizer from 80 to 180 kg N ha^{-1}. Despite the positive effects of N fertilization, Nam et al. (2001) found reduction in crop yield due to increased competition between weed and crop for N absorption. Barker et al. (2006) reported negative effect of high rate of N fertilizer in corn field, due to an overcome of leaf area index of weeds over corn. Begum et al. (2009) recommended low level of N fertilizer to overcome weed competiveness for better rice yield. Pourreza et al. (2010) have reported increase in weed competition with reduction in wheat yield by increased N fertilizer dosage. Behdarvand et al. (2013) discouraged the application of high N fertilizer for weed management, because of high N utilization efficiency of weeds than the crop.

Nitrogen fixers found, associated with rice roots, are a natural source of soil nitrogen in nitrogen deficient soils (Tobar, 2013). Potential of associative N_2-fixers has been documented as sustainable pool of soil organic N with supply of up to 113 kg N ha^{-1} to rice crop depending upon the ecosystem, cultural practices and rice variety grown (Ariosa et al., 2004). Recently, it has been found that associative nitrogen fixation can supply 20-25% of total nitrogen requirements in rice and maize (Montanez et al., 2012). More than 200 species of nitrogen fixing bacteria have been isolated from the rice field (Khan et al., 2008) and many species of diazotrophic bacteria like *Azotobacter*, *Herbaspirillum*, *Clostridium*, *Azospirillum* and *Burkholderia* were documented (Choudhury and Kennedy, 2004). Biopower, a mixture of such nitrogen fixers, is a natural mini-fertilizer factory that is much more an economical and safer source of plant nutrients than chemical fertilizers, for increasing agricultural production and improving soil fertility (Khan et al., 2008). Accordingly, the scientists of National Institute for Biotechnology and Genetic

Engineering (NIBGE), Faisalabad, Pakistan have isolated a number of bacterial strains from the soil and plant material collected from different areas of Pakistan. They characterized these bacterial strains belonging to genera *Azospirillum*, *Azotobacter*, *Pseudomonas*, *Zoogloes*, etc., for cereals. After trying a number of local materials, a suitable carrier material has been devised to ensure maximum survival of the inoculated bacteria during storage and transportation. These biocultures are patented as Biopower. Biopower prepared by scientists at NIBGE is being marketed by Pakistan Innovative Biotechnology Service (PIBS), a subsidiary of Al-Technique Corporation of Pakistan (Pvt.) Ltd. Since microorganisms in Biopower are claimed to fix nitrogen at the surface of roots of rice, therefore, we hypothesized that weed competition may be reduced by Biopower as natural source of nitrogen available to rice, but not to the weeds. Therefore, this present field study was carried out to investigate the potential of Biopower in increasing rice yield, under weed infestation, in soils amended with farmyard manure or different rates of N fertilizers.

MATERIALS AND METHODS

Selection of weeds

Four weed species viz., *Echinochloa colonum*, *Cyperus rotundus*, *Marsilea minuta* and *Paspalum paspaloides* were selected because of their high frequency of occurrence in rice fields of the Punjab, Pakistan (Rabbani and Bajwa, 2001). These weeds caused 54-68% yield losses in rice when grown in 1:1 ratio of weed and rice plants (Rabbani et al., 2011). Seeds of *E. colonum*, *M. minuta* and *P. paspaloides* were collected during the previous season from rice fields and sown in separate plots in Botanical Garden, University of the Punjab, Lahore, Pakistan, four weeks after sowing rice seeds. Similarly, tubers of *C. rotundus* were collected and sown in a plot.

Experimental design and treatments

Experiment was conducted in Botanical Garden, Punjab University, Quaid-e-Azam Campus, Lahore, Pakistan. Soil of experimental area was sandy loam in texture with pH 7.5, organic matter 0.70%, exchangeable potassium 101 mg kg^{-1} and available phosphorus 6.6 mg kg^{-1}.

Experiment was laid out in split-split plot design with soil amendments as main plots, Biopower as sub-plots and weed species as sub-sub-plots. The size of each sub-sub plot was 1.5 m × 1.5 m. Three soil amendments were, i) farmyard manure (FYM) + ¼ NPK, ii) full or recommended dose of nitrogen (N), phosphorus (P) and potassium (K) and, iii) half dose of nitrogen (½ N) plus recommended doses of P and K. Farmyard manure at 15 t ha^{-1} was mixed in the soil 2 weeks before the rice transplantation. Recommended dose of N at 132 kg ha^{-1} and ½ dose of N at 66 kg ha^{-1} as urea, P_2O_5 at 68 kg ha^{-1} as triple-super-phosphate and K_2O at 62 kg ha^{-1} as potassium sulphate were applied in the soil of respective field plots. Whole dose of P_2O_5 and K_2O and half dose of N were applied as basal at the time of rice transplantation while remaining N was top dressed prior to flowering of rice. A basal dose of ¼ NPK was also applied in the FYM amended soil at the time of rice transplantation. A recommended dose of $ZnSO_4$ at 10 kg ha^{-1} was applied after 3 weeks of rice transplantation in all treatments, as local soil was deficient in zinc.

Biopower application and rice transplantation

Rice seeds of variety "Super Basmati" were surface sterilized with 1% sodium hypochlorite for five minutes and thoroughly washed with sterilized water. These seeds were sown in a 90 × 60 cm^2 plot to raise rice nursery.

Biopower was obtained from National Institute for Biotechnology and Genetic Engineering (NIBGE), Faisalabad, Pakistan. Its inoculum was prepared by mixing 375 g of Biopower in 4 liters of water. One-month-old rice seedlings were uprooted from nursery plot and their roots were immersed in the Biopower inoculum for half an hour. Then the inoculated and un-inoculated rice seedlings were transplanted in the respective plots. Rice seedlings were transplanted in six rows having six hills in each row keeping inter and intra row spacing of 20 cm. Single rice seedling was transplanted per hill. Flooded condition in the field plots was maintained by irrigation with good quality tube-well water.

Transplantation of weed seedlings

Two weeks after rice transplantation in the field plots, 14 day-old seedlings of various weed species viz. *E. colonum*, *C. rotundus*, *M. minuta* and *P. paspaloides* were transplanted in the respective sub-sub plots with 1:1 ratio of weed and rice plants. A mixed weed treatment was also included. Weed free treatments in each of the three soil amendments served as controls.

Harvesting and data collection

Plants of weeds and rice were harvested at maturity. At the time of harvest, rice plants of each treatment were uprooted carefully from each plot and washed under tap water to remove soil debris. Number of tillers per plant and shoot length were recorded. Then root and shoot of each plant were separated, oven dried at 70 °C for 72 hours and weighed. Grain yield per plant and weight of 1,000 grains were also recorded. Grain yield was converted to ton ha^{-1}. Harvest index was calculated as economic yield expressed in percentage over biological yield. Percentage losses in root-shoot and grain's yield due to various weeds in the presence or absence of Biopower were also calculated. Percentage increase in yield due to Biopower application was also recorded. Weed biomass in each treatment was recorded and transformed to ton ha^{-1}.

At flowering stage, shoot nitrogen content was determined by wet digestion with H_2SO_4 according to the Microkjeldahl method (Yoshida et al., 1976).

Statistical analysis

The data recorded were subjected to analysis of variance followed be separation of treatment means by Duncan's Multiple Range Test at 5% level of significance. The two corresponding treatments with and without Biopower application were compared by applying t test.

RESULTS AND DISCUSSION

Effect of weeds and Biopower on vegetative growth of rice

In all the three soil amendment systems, the highest plant height of rice (90-114 cm) was recorded in weed free plots. Presence of weeds exhibited variable effects on plant height of rice in different soil amendments. In farmyard manure amendment, plant height of rice was significantly shorter due to presence of different weeds. Plant height was 83 to 106 cm in different weed treatments as compared to 114 cm in weed free plots. In NPK amendment plots, all weeds, except *E. colonum*, significantly reduced plant height of rice over weed free plots. In ½N-PK amendment, only mixed weeds had a significant adverse effect on this shoot growth parameter of rice. Likewise, the effect of weeds on number of tillers, shoot dry weight and root dry weight of rice was more pronounced in farmyard manure and NPK than in ½N-PK amendment (Table 1).

In general, Biopower application has significantly increased various shoot and root growth variables of rice both in control and in different weed treatments in ½N-PK and farmyard manure amendments. Conversely, in NPK amendment, Biopower application rarely enhanced plant height or shoot and root dry biomasses (Table 1).

Effect of weeds and Biopower on yield components of rice

In weed free plots, the highest grain yield of rice (2.56 ton ha^{-1}) was recorded in the plots where farmyard manure was applied, followed by NPK (2.0 ton ha^{-1}) and ½N-PK (1.28 ton ha^{-1}) amendment plots. All the weeds variably and significantly reduced grain yield of rice in ½N-PK and farmyard manure amendments by 12-56% and 38-75%, respectively. In NPK amendment,

Table 1 **-** Effect of weeds and Biopower application on root and shoot growth of rice in different soil amendments

Treatments	Plant height (cm)		Tillers per plant		Shoot dry wt. (g)		Root dry wt. (g)	
	BP^-	BP^+	BP^-	BP^+	BP^-	BP^+	BP^-	BP^+
½N-PK amendment								
Control (weed free)	90 a	100 a*	10 ab	16 a***	14 a	26 a	4 a	6.5 a*
Echinochloa colonum	88 a	98 a*	11 a	13 bc	12 ab	17 b	3.4 a	4 b
Cyperus rotundus	84 a	97 a**	8 bc	11 c*	8 d	18 b	2.8 ab	5.4 ab*
Marsilea minuta	88 a	101 a**	11 a	12 bc	10 bd	20 b	3.3 a	5.6 ab**
Paspalum paspaloides	90 a	95 a*	10 ab	14 ab***	11 ac	17 b	2.9 ab	4.5 b**
Mixed weeds	77 b	87 b*	7 c	10 c*	8 cd	10 c	2 b	4 b***
NPK amendment								
Control (weed free)	103 a	106 a	15 a	18 a*	20 a	23 a	7 a	11.5 a**
Echinochloa colonum	98 ab	100 ab	14 ab	15 b	19 ab	22 a	6 ab	6.4 ab
Cyperus rotundus	90 c	93 cd	9 d	11 cd**	13 c	16 b	3 c	5 b
Marsilea minuta	92 bc	90 d	13 bc	12 cd	14 bc	17 ab	5.6 ab	5.6 b
Paspalum paspaloides	91 c	97 bc**	12 bc	13 c	15 ac	20 ab	4.6 bc	4.8 b
Mixed weeds	87 c	91 cd	11 cd	10 d	15 ac	15 b	4.3 bc	4.8 b
Farmyard manure amendment								
Control (weed free)	114 a	120 a*	21 a	25 a*	35 a	45 a	7.2 a	15 a***
Echinochloa colonum	106 b	114 b*	15 b	12 bc	22 b	24 b	3 b	12 a***
Cyperus rotundus	91 c	112 b***	10 d	14 bc*	11 c	28 b	2.6 b	7.5 b**
Marsilea minuta	84 cd	115 ab***	10 cd	18 b***	16 bc	37 a	3.4 b	7.8 b**
Paspalum paspaloides	89 cd	104 c***	13 bc	17 b**	14 c	27 b	2.7 b	7.3 b**
Mixed weeds	83 d	101 c***	7 d	11 c*	13 c	19 b	2 b	5 b***

BP^- = Biopower absent. BP^+ = Biopower present. In each soil amendment, values with different letters in a column show significant difference ($P\leq0.05$) as determined by DMR Test. *, **, ***, Show significant difference between two corresponding treatments with and without Biopower application, at 5, 1 and 0.1% level of significance, respectively, as determined by t test.

different weeds reduced rice grain yield by 12-40%. The adverse effect of all the weeds except *E. colonum* was significant in NPK amendment (Figure 1, Table 2). *C. rotundus* and mixed weeds caused maximum yield losses in all the soil amendments. Losses due to *C. rotundus* were as high as 59% in FYM, 36% in NPK and 31% in ½N-PK amendment, while mixed weeds caused up to 75%, 40% and 56% yield losses in FYM, NPK and ½N-PK amendments, respectively. *C. rotundus* is among the world's most harmful weeds and it poses serious problems in rice and other economic important crops in many parts of the world (Iqbal et al., 2012).

Biopower application enhanced grain yield in all the treatments. However, the effect was weed species specific and also varied with type of soil amendment. The most pronounced effect of Biopower on grain yield was recorded in farmyard manure amendment plots where Biopower application significantly enhanced grain yield in all the weed treatments by 40-150%. The highest increase in yield was recorded in mixed weeds (150%) followed by in *M. minuta* (115%), *C. rotundus* (107%), *P. paspaloides* (83%), *E. colonum* (40%), and control (12%). The effect of Biopower application was also highly pronounced in ½N-PK amendment where Biopower significantly increased grain yield of rice in control plots as well as in various weed treatments by 38-90% over corresponding non-Biopower treatments. The highest increase in grain yield of rice due to Biopower application was recorded in plots infested with *C. rotundus* (90%) followed by 72% in *E. colonum*, 71% in mixed weeds, 48% in control, 43% in *P. paspaloides* and 38% in *M. minuta* infested plots. The effect of Biopower application on grain yield in NPK amendment was the least pronounced where Biopower application enhanced grain yield in control and different weed treatment plots only by 6 16%. The effect of Biopower application was only significant in *P. paspaloides* infested plots (Figure 2, Table 2). Biopower contains nitrogen fixing microorganisms. Some free living diazotrophic species of bacteria fix atmospheric nitrogen and, therefore, enhance crop growth. In addition, these bacteria produce plant growth hormones, or enhance root growth and thereby increase nutrient absorption capacity and avoid plant stresses. It has been proposed that PGPR is able to produce antibodies or siderophores that can suppress deleterious microbes or produce phyto hormones or other growth promoting compounds that directly affect plants or somehow enhance their nutritional status. The direct uptake of bacterial produced IAA by plants has also been observed (Gupta et al., 2015).

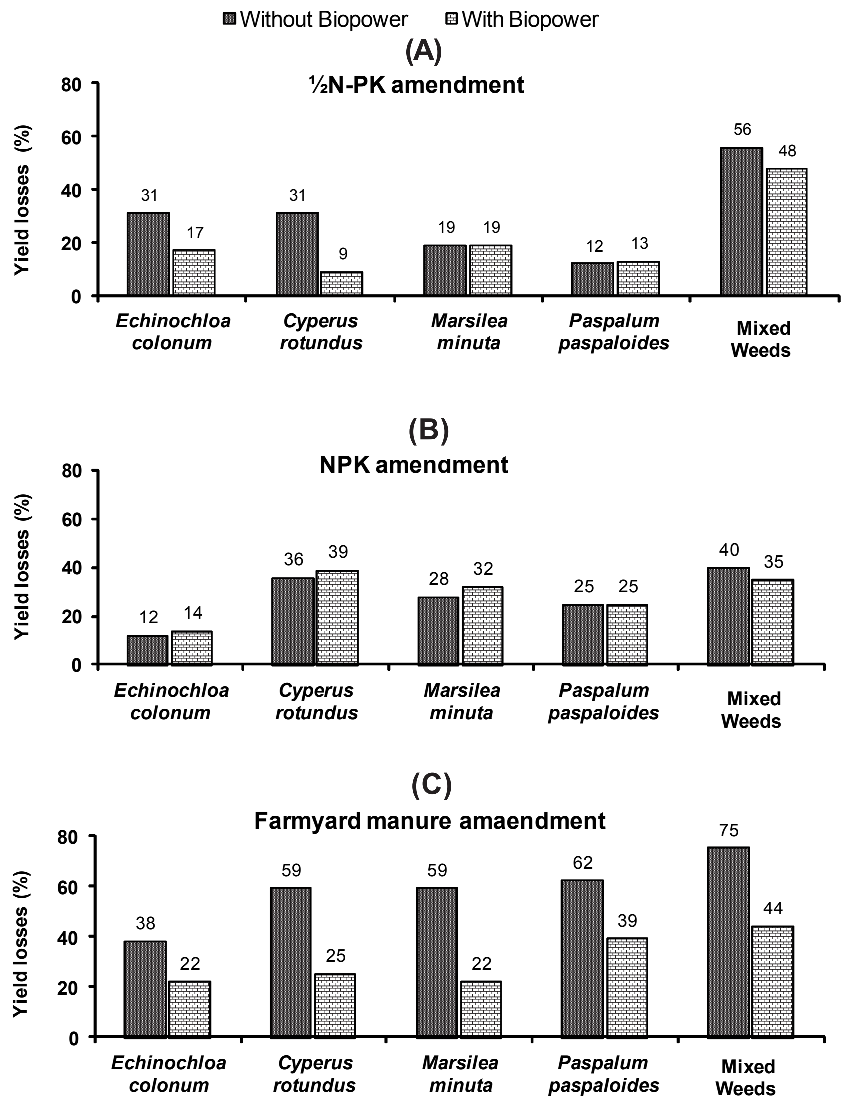


Figure 1 - Percentage losses in grain yield of rice due to different weed species in the presence and absence of Biopower application.

A 1,000 grain weight in control varied from 19.2 g in ½N-PK to 20.5 g in NPK and 20.8 g in farmyard manure amendment. Different weeds reduced 1000-grain weight by 2-11% in ½N-PK, 0-5% in NPK and 3-20% in farmyard manure amendment. In farmyard manure amendment, the adverse effect of all the weeds except *E. colonum* was significant while in ½N-PK amendment plots, only the effect of *M. minuta* and mixed weeds was significant. In contrast, in NPK amendment plots, the effect of all the weeds on 1,000 grain weight was insignificant. Biopower application generally enhanced 1,000 grain weight in ½N-PK and farmyard manure amendments (Table 2).

The effect of weeds on harvest index was highly variable in different soil amendments in the absence of Biopower application. In ½N-PK amendment, harvest index was significantly reduced by 13%, due to each of *E. colonum* and mixed weeds. In NPK amendment, only mixed weeds significantly reduced harvest index by 8%. In farmyard manure amendment, *C. rotundus* infestation significantly increased harvest index by 12% while mixed weeds reduced this

Table 2 - Effect of weeds and Biopower application on yield, harvest index and shoot N content of rice in different soil amendments

Treatments	Grain yield (t ha^{-1})		1000-grains wt. (g)		Harvest index (%)		Shoot N content (%)	
	BP$^-$	BP$^+$	BP$^-$	BP$^+$	BP$^-$	BP$^+$	BP$^-$	BP$^+$
½N-PK amendment								
Control (weed free)	1.28 a	1.84 a**	19.2 a	20.0 a**	47 a	42 b*	2.3 a	2.7a**
Echinochloa colonum	0.88 b	1.52 ab**	18.3 ab	19.7 ab**	41 b	48 a**	2.0 bc	2.2bc
Cyperus rotundus	0.88 bc	1.68 ab**	18.8 ab	19.2 ab	50 a	47 a	2.1 b	2.5ab**
Marsilea minuta	1.04 ab	1.44 b*	17.1 c	19.8 ab***	49 a	41 b***	1.9 cd	2.7a***
Paspalum paspaloides	1.12 ab	1.60 ab*	18.7 ab	18.8 b	50 a	49 a	2.0 bd	2.4bc**
Mixed weeds	0.56 c	0.96 c***	18.0 bc	19.9 a*	41 b	46 a**	1.8 d	2.2c*
NPK amendment								
Control (weed free)	2.00 a	2.24 a	20.5 a	20.6 a	48 ab	45 a**	2.65 a	2.7 a
Echinochloa colonum	1.76 a	1.92 ab	20.2 a	20.7 a*	47 b	46 a	2.4 ab	2.0 c
Cyperus rotundus	1.28 b	1.36 c	20.0 a	20.2 a	50 a	45 a***	2.4 ab	2.0 c
Marsilea minuta	1.44 b	1.52 c	20.5 a	20.5 b	47 b	46 a	1.9 c	2.4 b***
Paspalum paspaloides	1.44 b	1.68 c**	20.2 a	19.5 b	47 b	46 a	2.3 ac	2.5 a
Mixed weeds	1.20 b	1.36 c	19.5 a	19.5 b	44 c	46 a	2.2 bc	2.3 b
Farmyard manure amendment								
Control (weed free)	2.56 a	2.88 a	20.8 a	22.0 a***	43 b	38 b**	2.3 a	2.5 a*
Echinochloa colonum	1.60 b	2.24 b**	20.1 ab	20.5 b	45 b	44 a	2.2 ab	2.4 a*
Cyperus rotundus	1.04 c	2.16 bc***	19.8 b	20.4 b	49 a	44 a**	2.1 cd	2.2 b
Marsilea minuta	1.04c	2.24 b***	16.7 c	20.3 b***	41 b	49 a	2.2 bc	2.5 a**
Paspalum paspaloides	0.96 c	1.76 d **	17.0 c	20.1 b***	42 b	39 b	2.1 bd	2.3 ab***
Mixed weeds	0.64 d	1.60 d***	16.6 c	20.3 b***	35 c	46 a***	2.1 b	2.2 b

BP$^-$ = Biopower absent. BP$^+$ = Biopower present. In each soil amendment, values with different letters in a column show significant difference (P≤0.05) as determined by DMR Test. *, **, ***, Show significant difference between two corresponding treatments with and without Biopower application, at 5, 1 and 0.1% level of significance, respectively, as determined by t test.

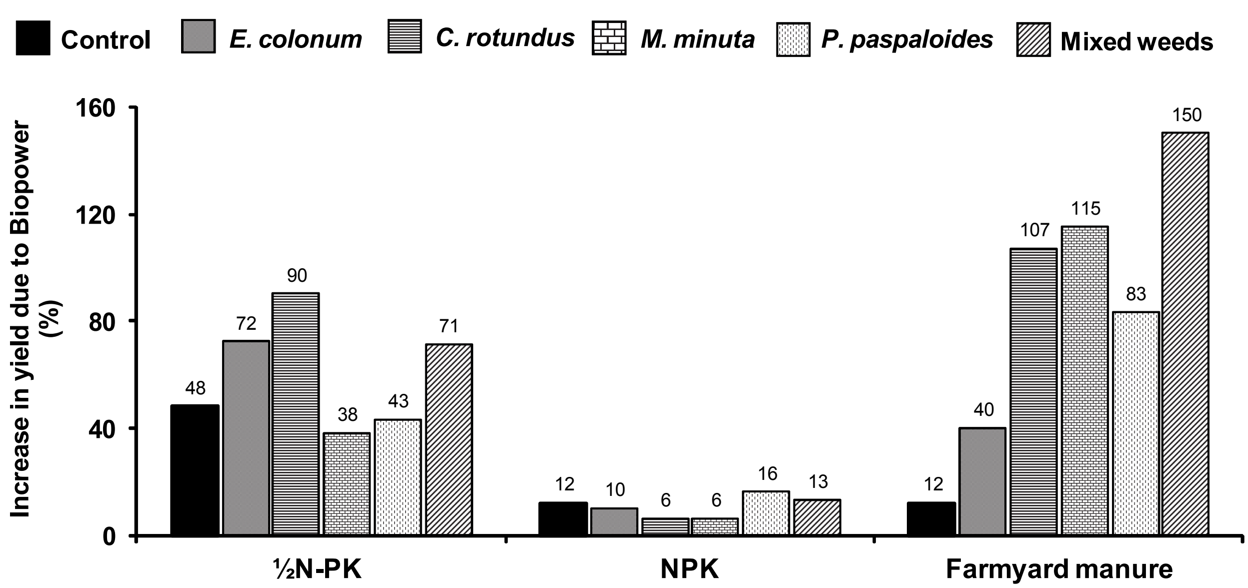


Figure 2 - Percentage increase in grain yield of rice due to Biopower application in the presence and absence of weeds.

parameter by 19% over weed free control (Table 2). Biopower application had both negative and positive effect on harvest index. Biopower application has significantly reduced harvest index in weed free control in all the three soil amendments possibly because of more effect on vegetative than on reproductive growth of rice plants. However, in mixed weed treatment, Biopower application significantly enhanced harvest index in ½N-PK and farmyard manure amendments. In individual weed treatments, Biopower application exhibited variable effects on harvest index in the three soil amendment systems (Table 2).

Effect of weeds and Biopower on shoot nitrogen content of rice

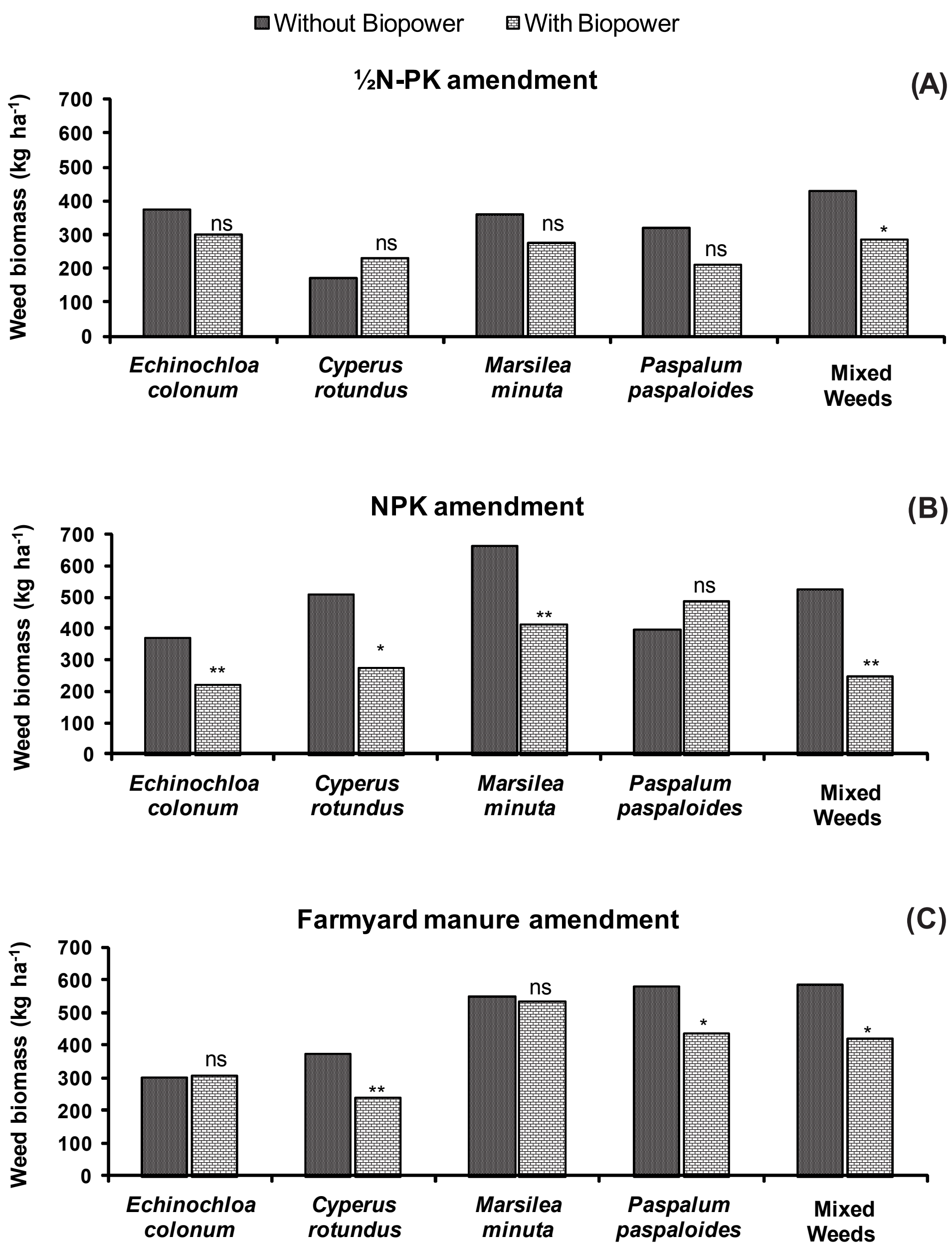
In general, the highest shoot N content was recorded in weed free plots in all the three soil amendment systems. Different weed species had variable effects on shoot N content of rice that also varied with the type of soil amendment system. In ½N-PK, all the weed species significantly reduced shoot N content by 9-22%. In NPK amendments, the adverse effect of weeds on shoot N content of rice was significant in case of *M. minuta* and mixed weed. In farmyard manure, all weeds except *E. colonum* significantly reduced shoot N content by 4-9%. Biopower application enhanced shoot N content in all the treatments to variable extents. The most pronounced effect of Biopower on shoot N content was recorded in ½N-PK amendments where it significantly enhanced N content in all the treatments except *E. colonum*. Likewise, in farmyard manure amendment, Biopower application significantly increased N content in all treatments except *C. rotundus* and mixed weeds. The least effect of Biopower application on shoot N content of rice was recorded in NPK amendment where it enhanced N content only in *M. minuta* treatment (Table 2). The role of associative and free living microorganisms in the rhizosphere of plants has been acknowledged to play an important role in nitrogen nutrition of plants (Gupta et al., 2015). In the present study, enhanced plant growth and yield of rice due to Biopower application seems to be due to enhanced nitrogen nutrition by microorganisms in the Biopower.

Effect of Biopower on weed biomass

Weed dry biomass varied with weed species, soil amendment and Biopower application. In general, weed biomass was higher in farmyard manure and NPK amendments than in ½N-PK amendment. In the absence of Biopower, weed biomass ranged from 173-428 kg ha^{-1}, 375-668 kg ha^{-1} and 300-585 kg ha^{-1} in ½N-PK, NPK and farmyard manure amendments, respectively. Generally, mixed weed showed higher biomass than individual weed species in all the three soil amendment systems (Figure 3). Recently, Ahmed et al. (2015) have reported that enhanced nitrogen rates increased biomass and competitive ability of some weeds. However, Azadbakht et al. (2012) have reported a contrasting trend of declined weed density with increased rate of N application, attributing it to more competitive crop growth.

Biopower application has variably reduced weed biomass in different soil amendments. The effect of Biopower was most pronounced in NPK amendment followed by farmyard manure and ½N-PK amendment. In NPK amendment, Biopower application significantly reduced biomass of *E. colonum*, *C. rotundus*, *M. minuta* and mixed weeds by 40%, 45%, 38% and 53%, respectively. Conversely, the effect of Biopower application on biomass of *P. paspaloides* was insignificant (Figure 3B). Likewise, in farmyard manure amendment, Biopower application significantly decline biomass of *C. rotundus*, *P. paspaloides* and mixed weeds by 36%, 25% and 28%, respectively, while showed non-significant effect on biomass of *E. colonum* and *M. minuta*. In ½N-PK amendment, Biopower application significantly reduced biomass of mixed weeds by 33% (Figure 3A, C). It is likely that Biopower application enhanced rice growth, consequently weed growth was suppressed due to better competition of the crop for space, light and other available resources.

In conclusion, Biopower has great biofertilizer potential to promote crop growth and yield of rice, which consequently suppresses growth of weeds. The associative N_2-fixing diazotroph species in Biopower enhanced plant N contents further optimized the nutritional requirement and growth conditions for the rice crop to compete well with weeds. There are clear indications that the weed suppressive potential of Biopower can be better exploited by employing organic amendment such as farmyard manure and/or using low rate of inorganic N fertilizer.



*, **, show significant difference between two corresponding treatments with and without Biopower application at P≤0.05 and 0.01, respectively. ns: shows non-significant difference.

Figure 3 **-** Effect of Biopower application on weed dry biomass in different soil amendments.

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