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Research Article

Wheat Crop Productivity in Berseem-Rice -Wheat Cropping System in Comparison with the Conventional Wheat-Rice-Wheat Cropping System Planted in Rice-Wheat Area of Punjab Pakistan

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Abstract

Rice-wheat cropping system has an important role in ensuring the food security of Pakistan. Inclusion of a leguminous crop like Berseem (Egyptian clover) in this cropping system can have positive effects on the yields of subsequent crops. To find out the effects of different cropping systems on the productivity of wheat crop, during crop season 2014-15, wheat crop adaptation plots were planted on 10 different farmers' fields in five major rice crop growing districts of Punjab province including Sheikhupura, Hafizabad, Mandi Bahaouddin, Gujranwala and Sialkot in two different cropping systems i.e., wheat-rice-wheat and berseem-rice-wheat. Although there were variations in grain yields of wheat crop planted under both cropping systems on different sites, but on overall basis 5.4 % more grain yield was recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in conventional wheat-rice-wheat cropping system. In case of some sites less wheat crop grain yields were recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in wheat-rice-wheat cropping system and it ranged from 7.5% to 16.7% but in case of maximum number of sites, more wheat crop grain yields were recorded in case of berseem-rice-wheat cropping system as compared to the crop planted in wheat-rice-wheat cropping system and these differences ranged from 5.47% to 30.76% respectively. This shows that planting of berseem crop instead of wheat after two to three years can be helpful in getting the more yields of subsequent crops, and it is also soil health and environment friendly.

Keywords: Rice, Wheat, Berseem, Cropping System, Wheat Yield.

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Introduction

Rice-wheat cropping system (RWCS) is one of the world's largest agricultural production systems, which covers an area of about 26 M ha and extends over the Indo-Gangetic Plains (IGP) in South Asia (Chauhan et al., 2012 and Shweta and Malik, 2017). Both rice and wheat crops have been cultivated in South Asia (Bangladesh, Bhutan, India, Nepal & Pakistan) and China for over 1000 years and more than 85% of the RWCS practiced in South Asia is located in the Indo-Gangetic Plains. The IGP is a fertile area of 225 M ha, which includes most of eastern and northern India, whole of Bangladesh, Nepal and Pakistan. The rice-wheat cropping system occupies 32% and 42% of the total rice and wheat area respectively (Saharawat et al., 2012). In Pakistan, Rice – Wheat cropping system is being practiced on an area of about 2.2 M ha (Nawaz and Farooq., 2016).

Wheat (*Triticum aestivum* L.) and Rice (*Oryza sativa* L.) are the two main cereal crops of Pakistan. During 2023-24 wheat crop was planted on an area of 9.6 million ha and its total production was 31.4 million tonnes, while the total area under rice crop was 3.6 million ha with the total production of 9.9 million tonnes. Wheat crop is cultivated under the different cropping systems like cotton-wheat, rice-wheat, maize-wheat and fallow-wheat etc. Rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system is one of major cropping system of the Punjab province.

According to Nawaz et al., (2019), rice-wheat cropping system (RWCS), due to different factors like declining soil fertility, depletion of ground water, rising problem of salinity and alkalinity, increasing problems of weeds, insects, pests and diseases, is showing yield stagnation. Sweta and Malik, (2017) have also reported same kinds of issues from India. According to them it might be because, both rice and wheat are heavy feeders and nutrient - exhaustive crops and the amount of external nutrients applied to rice and wheat can not keep pace with the amount of nutrients removed from the soil, which leads to soil and production exhaustion (Ladha et al., 2003 and Singh et al., 2005). It has also been reported that the well-fertilized crops of rice and wheat meet about 50.8% of their nitrogen (N) requirements from the soil (Ravisankar et al., 2014), which may result in poor factor productivity of RWCS (Singh et al., 2019). It has been also reported that the continuous use of chemical fertilizers without nutrient recycling has led to a great loss of soil fertility and productivity (Ram N., 1995). It is the fact that cereal-cereal sequences are more exhaustive, unsustainable and put a heavy demand on soil resources as compared to the cereal-legume and cereal-oilseed sequences.

It has been reported that inclusion of legume crops in the system not only fixes atmospheric N but also enriches soil fertility, increases nutrient availability, improves soil structure, reduces disease incidence, promotes mycorrhizal colonization (Wani et al., 1995), and ultimately helps to sustain the long-term productivity of cereal – based cropping systems. The substitution of wheat with berseem (*Trifolium alexandrinum*

L.) only once or twice in a three – year cycle of the rice-wheat cropping system has also been recommended (Banjara TR et al., 2021).

Berseem (*Trifolium alexandrinum* L.) is one of the most important leguminous fast-growing, high-quality forages that is mainly cut and fed as a green chopped forage and it can also be used as a green manure crop. It is an annual, sparsely hairy, erect forage legume, 30 to 80 cm high, with the shallow taproot system. It is a N-fixing legume, which is not only used by the Berseem (*Trifolium alexandrinum* L.) itself but also by succeeding crops. It regrows after cutting and helps in weed control. It gives 4-6 cutting yielding from 40-50 t ha^{-1} contains calcium and other vitamins which increases milk production (Ali., 2012). Legume crops enhance 0.9% organic matter, 0.12% nitrogen, 2.8 ppm available phosphorous, 52 ppm available potassium, reduce pH of soil up to 0.4 and increase 0.5% organic carbon after its harvest compared to rice-wheat cropping system (Ali et al., 2012). According to a study of Rai et al., (2013), the cowpea and Egyptian clover also complement the cropping system's soil SOC pools and productivity because of spatial and temporal annidation and different rooting behaviors.

The purpose of these adaptation plots was to promote leguminous based rice-wheat cropping system i.e., Berseem-Rice-Wheat cropping system in comparison with the conventional Wheat-Rice-Wheat cropping system on the farmer's fields in the different rice producing districts of Punjab province.

Materials and Methods

The adaptation plots of wheat crop were planted on different farmer's fields in the 5 different main rice crop producing districts of Punjab province including Sheikhupura, Hafizabad, Mandi Mandi Bahaouddin, Gujranwala and Sialkot, the detail of which is given in Table 1. Those farmers were selected who had planted berseem (Egyptian clover) crop as a fodder on some area of their land during rabi season 2013-14. So, on those farmers' fields wheat crop was planted in two different cropping systems (treatments) i.e., 1. Wheat cop planted in conventional (i.e., Wheat-Rice-Wheat) cropping system and 2. Wheat crop planted in legume-based (i.e., Berseem-Rice-Wheat) cropping system. Before planting of crop on all sites, soil samples were collected from the 0-40 cm soil depth and analyzed for various soil factors by using the standard procedures (Table 1). Wheat variety Borlaug-2016 was planted by keeping the seed rate of 50 kg/acre and nutrients i.e., N & P were applied @ 120: 90 kg/ha in the form of Urea and Diammonium Phosphate (DAP) at the time of land preparation for planting of wheat crop. On all sites weeds were controlled with the application of appropriate herbicides and similarly water was applied to the crop according to its requirements. Data was recorded regarding crop germination, grain yields and different yields components. Crop germination data was recorded by using the one square meter quadrate, randomly from three different points and similarly for grain yields and different yield components crop samples were randomly harvested from all sites and from both treatments by using the one square meter quadrate. Tillers were counted and data was recorded regarding plants heights, spike lengths (cm) and number of spikelets per spike. Samples were weighed for biological yields and after drying, these samples were thrashed for grain yields. Data was analyzed by using Randomized Complete Block Design (RCBD) with Factorial arrangement having two factors i.e., planting sites and cropping systems with three replications by using the Statistix 8.1 software at 5% alpha level, while Tukey test was applied for comparison of means.

Table 1. Soil analysis of 0-40 (cm) top soil depth of the different sites of the rice-wheat area of Punjab before the sowing of wheat crop in different rotations i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) during the cropping year 2014-15.

Site. No	Site Name	Crop rotation	Soil Texture	Saturation%	Soil pH	E.C. dsm^{-1}	Organic matter%	Available-P mg kg^{-1}	Available-K mg kg^{-1}	Total Nitrogen (%)	TOC (%)/ SOC
1.	Munir Farm Mureedkay, District Sheikhupra	W-R-W	Loam	38	7.77	1.27	0.69	8.2	120	0.035	0.40
		B-R-W	Loam	39	7.28	2.91	0.62	7.9	120	0.031	0.36
2.	Liaqat Bhatti Farm, Mureedkay District Sheikhupra	W-R-W	Loam	39	7.31	3.1	0.53	5.2	160	0.027	0.31
		B-R-W	Loam	35	7.39	2.7	0.49	4.3	120	0.025	0.29
3.	Village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra	W-R-W	Loam	36	7.81	1.56	0.69	7.3	100	0.035	0.40
		B-R-W	Loam	38	7.79	1.20	0.50	7.1	100	0.025	0.29
4.	Village Nakay Wal Bosal, District Mandi Bahaouddin	W-R-W	Loam	38	7.89	1.05	0.60	6.3	140	0.030	0.35
		B-R-W	Loam	37	7.83	1.29	0.67	8.1	120	0.034	0.39
5.	Bhatti Chack, District Hafizabad	W-R-W	Loam	41	8.06	1.42	0.59	5.2	100	0.030	0.34
		B-R-W	Loam	36	8.01	1.21	0.61	5.2	100	0.031	0.35
6.	Village Gagay Wali, District Gujranwala	W-R-W	Clay	47	7.53	1.91	0.57	4.3	80	0.029	0.33
		B-R-W	Loam	39	7.51	2.40	0.53	5.1	80	0.027	0.31
7.	Mushtaq Cheema farm village Begowala, District Sialkot	W-R-W	Clay	48	7.71	0.75	0.63	5.3	100	0.032	0.37
		B-R-W	Loam	40	7.69	1.07	0.55	5.7	100	0.028	0.32

Site. No	Site Name	Crop rotation	Soil Texture	Saturation%	Soil pH	E.C. dsm^{-1}	Organic matter%	Available-P mg kg^{-1}	Available -K mg kg^{-1}	Total Nitrogen (%)	TOC (%)/ SOC
8.	Ch. Farooq farm, village Begowala, District Sialkot	W-R-W	Loam	40	7.79	0.75	0.62	6.4	120	0.031	0.36
		B-R-W	Loam	39	7.62	1.20	0.60	6.2	100	0.030	0.35
9.	Village Langay, District Sialkot	W-R-W	Loam	38	8.06	2.18	0.63	7.6	100	0.032	0.37
		B-R-W	Loam	40	8.01	1.23	0.60	8.8	120	0.030	0.35
10.	Village Porab, District Sialkot	W-R-W	Loam	36	7.61	0.88	0.53	6.9	120	0.027	0.31
		B-R-W	Loam	36	7.71	0.87	0.60	5.2	100	0.030	0.35

Results and Discussion

Significant differences in crop germination, plant height, and different yield components like spike length, spike lets per spike, biological yields and grain yields were recorded in case of wheat crop which was planted on different sites under the different cropping systems (Table. 2 & Fig. 1). In case of different sites, maximum grain yield (4.01 t/ha) was recorded in case of Site-3 (village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra), followed by Site-5 (Bhatti Chack, District Hafizabad) having grain yield of 3.75 t/ha, while minimum grain yield (1.95 t/ha) was recorded in case of Site-10 (village Porab, District Sialkot) (Fig.1). Differences in grain yields of different sites might be mainly due to differences in soil and other different crop management practices. Similarly, variations in the grain yields under different cropping systems, except in case of Site-3 (village Jalhar Bhattian, Feroze Pur Watwan, District Sheikhupra), were recorded in case of both cropping systems (Fig. 2). In case of 5 different sites i.e., Sites 2 (Liaqat Bhatti Farm, Mureedkay District Sheikhupra), 4 (Village Nakay Wal Bosal Bosal, District Mandi Bahaouddin), 6 (Village Gagay Wali, District Gujranwala), 8 (Ch. Farooq farm, village Begowala, District Sialkot) and 9 (Village Langay, District Sialkot) more grain yields were recorded in case of berseem-rice-wheat rotation as compared with the wheat-rice-wheat rotation, having differences of 29.5%, 33.2%, 5.47%, 7.66% and 30.76% respectively, while in case of 4 different sites i.e., Site 1(Munir Farm Mureedkay, District Sheikhupra), 5(Bhatti Chack, District Hafizabad), 7(Mushtaq Cheema farm village Begowala, District Sialkot) and 10 (Village Porab , District Sialkot) more grain yields were recorded in case of rice-wheat rotation in comparison with the berseem - rice - wheat rotation having differences of 9.8%, 7.5%, 16.7% and 16.7% respectively (Fig.2).

Table 2. Wheat crop germination and different yield components as affected by the different crop rotations (i.e., Wheat-Rice-Wheat and Berseem-Rice-Wheat) planted on 10 different sites in rice – wheat area of Punjab during cropping season 2014-15.

Site No.	Crop rotation	Ger/m^2	P.H (cm)	S. length (cm)	No of S. let's/spike	Tillers/m^2	B.Y (t/ha)
1.	Wheat-Rice-Wheat	187.0abcde	93.0efdh	10.2cdef	18.1abc	334.0a	11.1abcd
	Berseem-Rice-Wheat	179.3cdef	95.1defg	9.9defg	18.8abc	257.7bcde	11.7abc
2.	Wheat-Rice-Wheat	184.7bcde	97.8bcde	10.9abc	18.8abc	253.3cdefg	9.4efg
	Berseem-Rice-Wheat	178.7cdef	104.9a	11.0ab	19.2ab	317.3a	11.9ab
3.	Wheat-Rice-Wheat	204.3a	97.1cdef	11.4a	19.4a	281.0bc	10.5bcde
	Berseem-Rice-Wheat	179.0 cdef	102.4ab	10.9abc	19.0abc	327.7a	11.5ab
4.	Wheat-Rice-Wheat	161.7fg	100.0abcd	10.3bcdef	18.1abc	221.7h	10.0cdef
	Berseem-Rice-Wheat	177.7cdef	100.2abc	10.4bcde	18.1abc	254.3cdef	10.7bcde
5.	Wheat-Rice-Wheat	175.0ef	100.8abc	10.6bcd	17.7c	281.3bc	12.3a
	Berseem-Rice-Wheat	176.0def	103.4a	11.0ab	18.6abc	252.7cdefg	11.0abcd
6.	Wheat-Rice-Wheat	152.7g	90.7ghi	10.4bcde	18.3abc	270.3bcd	9.7def
	Berseem-Rice-Wheat	195.7abc	89.8hij	10.2cdef	18.3abc	262.7bcde	9.5ef
7.	Wheat-Rice-Wheat	191.7abcde	92.6fgh	10.6bcd	18.8abc	242.7defgh	8.9fgh
	Berseem-Rice-Wheat	188.7abcde	92.3fgh	10.3bcdef	18.8abc	238.7efgh	8.8fgh
8.	Wheat-Rice-Wheat	184.0bcde	87.2ijk	9.4g	18.6abc	224.7fgh	7.1ij
	Berseem-Rice-Wheat	202.3ab	93.7efgh	9.8efg	17.9bc	252.3cdefg	8.0ghi
9.	Wheat-Rice-Wheat	183.0cde	82.9k	9.7fg	17.9bc	262.0bcde	7.9hi
	Berseem-Rice-Wheat	187.3abcde	85.8ijk	9.7fg	17.7c	223.7gh	8.0ghi
10.	Wheat-Rice-Wheat	178.0cdef	86.9ijk	9.9defg	18.3abc	242.3defgh	5.6k

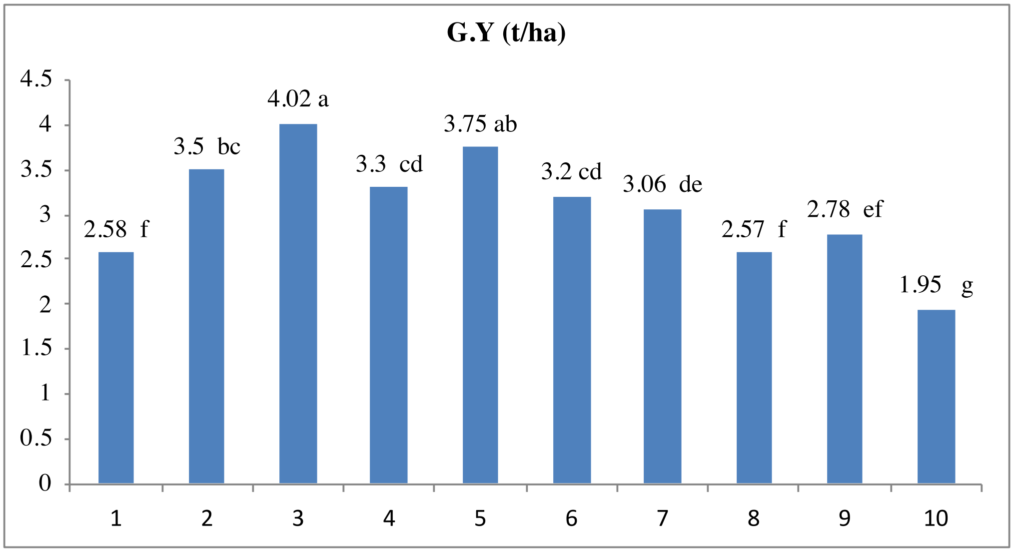

Fig. 1. Overall variations in grain yields of wheat crop (t/ha) planted 10 different sites under different cropping systems (i.e., Wheat-Rice-Wheat and Berseem-Rice-Wheat) in the rice-wheat area of Punjab during crop season 2014-15.

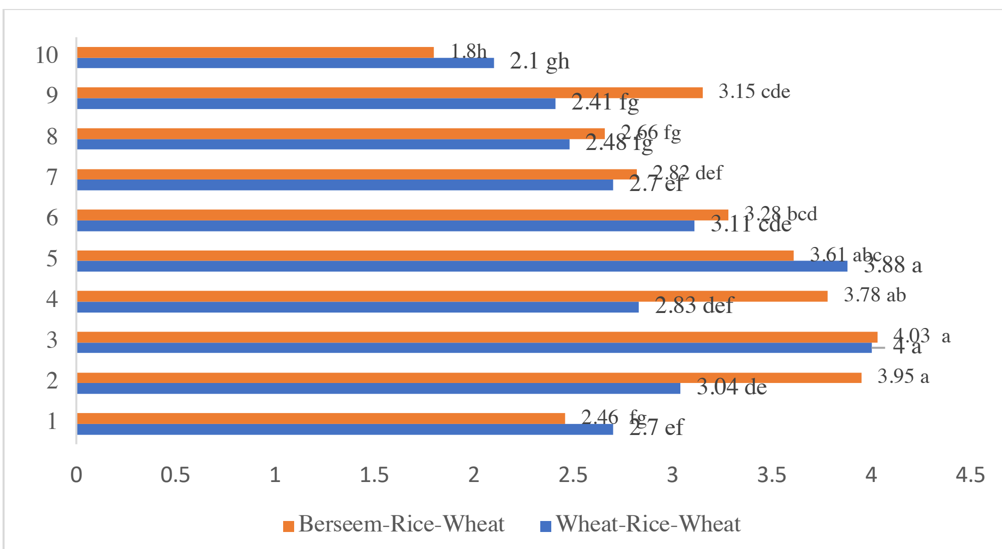

Fig. 2. Variations in grain yields of wheat crop (t/ha) as affected by the different cropping systems (i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) planted on 10 different sites in the rice-wheat area of Punjab.

Overall results of all sites show that there was 5.4 % more grain yield and 4.5% more biological yield in case of wheat crop planted in berseem-rice-wheat rotation as compared with the wheat - rice - wheat rotation (Fig.3). This shows that inclusion of leguminous crop in the rice-wheat cropping system increased wheat crop productivity, which might be mainly due to the increase of soil fertility. Similar results have also been reported by a field survey study of Sher et al., (2016), which was conducted to evaluate the impact of berseem (*Trifolium alexandrium* L) cultivation on productivity of subsequent crops in wheat - rice cropping system. For this purpose, one hundred and twenty farmers were interviewed through random selection procedure in agro-ecological zone of Gujranwala Punjab during rabi season 2013-14. The study concluded that in berseem-rice-wheat cropping system, the yield of rice and wheat crop was increased by 11% and 8% respectively. It has also been reported that, it also decreased the input cost of these crops by 5% and 3% respectively, due to atmospheric nitrogen fixation and also by reducing the weed population in subsequent crops. Singh et al., (2015), also reported that crop sequence having grain and fodder legume gave more grain yield of wheat as compared to the conventional rice-wheat cropping system. It is because, as legumes fix atmospheric nitrogen, which ultimately contributes for the better development of plant and biomass production. Similarly, according to Singh et al. (1997), inclusion of berseem in rice-wheat cropping system fulfills fodder requirements, increases the yields of subsequent crops, improves soil fertility and water holding capacity, reduces the nitrogen fertilizer requirement and similarly reduces the weed population in wheat crop. Rangaswami et al., (1990) also reported that legume crop assists in nutrient recycling within the system to economize and sustain the system and similarly it reduces the dependence on chemical fertilizers for crop production. Singh et al., (2007) also reported that it assists in habitat conservation rather than destruction. Soni and Kaur, (1984), reported that cultivation of a legume crop as a third crop during the summer season in the rice-wheat sequence proved better in enhancing the system rice equivalent yield. Wani et al., (1995), reported that inclusion of legumes in rotation hastened the N and P transformation. Parsad et al. (2011) and Anwar et al. (2010) reported that legumes had direct benefit of nitrogen fixation through root nodules to enhance soil fertility which could be used as companion as well as subsequent crop.

Similar types of issues have been reported from India, and according to Panwar et al., (2019), the sustainability of rice and wheat production is under threat due to the monotonous husbandry of RWCS and similarly it has been reported that the situation of nutrient mining is more alarming in the highly productive areas of IGP of India, where widely cultivated RWCS is supported with inadequate and unbalanced nutrient management practices (Singh et al., 2008).

Reduced cost of inputs of wheat sown in berseem-rice-wheat rotation as compared to the wheat-rice-wheat rotation has also been reported by Sher et al. (2016). This might be due to less usage of weedicides because weeds germinated in berseem were cut off along with fodder crop, so that there was less need of herbicide application. Likewise crop requires less nitrogenous fertilizer when sown after berseem. Similar findings have been reported by Singh et al. (1997) who reported that inclusion of legumes in multiple cropping systems offered many advantages to farmers. Legume-based cropping system also improves the yields of rice crop and according to Banjara TR et al., (2021), the grain yield of rice increased (4.7- 13.9%) in sequences that involved legume crops during winter and summer season as compared to rice-wheat sequence.

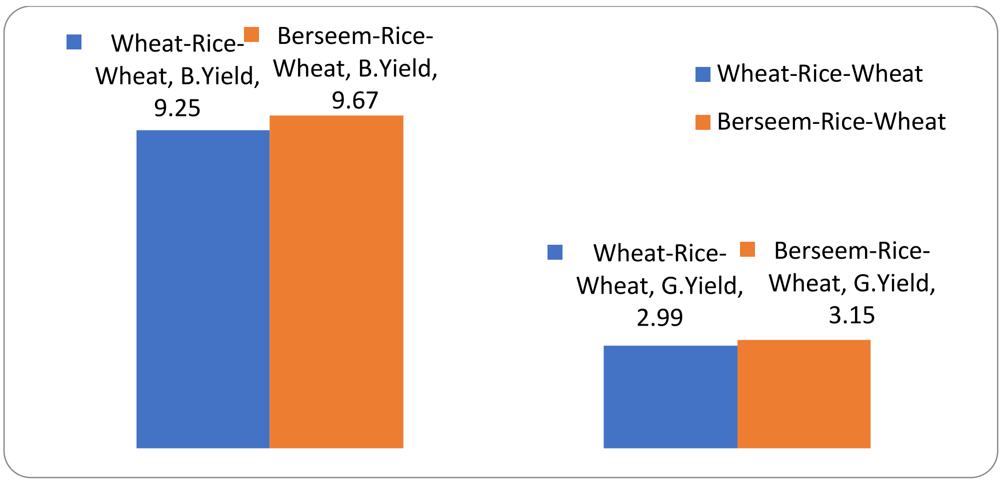

Fig. 3. Variations in Biological yields (t/ha) and Grain yields (t/ha) of wheat crop as affected by the different cropping systems (i.e., Wheat-Rice-Wheat (W-R-W) and Berseem-Rice-Wheat (B-R-W) planted on 10 different sites in the rice-wheat area of Punjab.

A suitable crop diversification assists in increasing farm income by better withstanding weather conditions, controls price fluctuations, ensures a balanced food supply, conserve natural resources, reduces use of chemical fertilizers and pesticides, ensures environmental betterment and also creates employment opportunities (Gill MS & Ahlawat IP, 2006). An integrated farming system (IFS) provides an opportunity to improve the economic yield per unit area and per unit time by intensification and diversification of crops and integration of allied enterprises. Similarly, according to Ali RI et al., (2012), leguminous based rice - wheat cropping system also gives better income mainly due to the production of higher grain and straw yield. Bohra et al., (2007); Mall et al., (2014) and Parsad, (2016) also reported that intensification of crop sequences with legumes increases yield and profitability.

As berseem improves soil fertility through N fixation from the atmosphere, and helps in reducing the weed population, so it is not only good for the soil health and environment due to the less use of fertilizers and herbicides but is also economically beneficial for the farmers. So, there is a dire need of promotion of planting of berseem in the rice-wheat cropping system.

Conclusion

It can be concluded that inclusion of berseem in the existing conventional rice-wheat cropping system can improve the yields of subsequent crops. Thus, the diversification of rice-wheat cropping system with berseem - rice - wheat can give better productivity and profitability in the rice-wheat areas of Punjab Pakistan. So, substitution of wheat with berseem only once or twice in a three – year cycle of the rice-wheat cropping system of Pakistan is not only economically favorable but it is also beneficial in terms of nitrogen fixation, reduces inputs requirement, good for soil health and environment. It can be beneficial for the livestock and dairy industry by supplying the ample quantity of fodder for this sector.

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