PRODUCTIVITY IN RICE-WHEAT CROP ROTATION OF PUNJAB: AN APPLICATION OF TYPICAL FARM METHODOLOGY

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ABSTRACT:- Rice-wheat cropping is among one of the most extensive systems in Pakistan and nearly three-fifth of this area falls in the Punjab province. The continuous sequential cropping has observed problem of stagnation of the rice-wheat productivity. The rational thinking urges to diagnose the problems of the area explaining the cause and effect scenario of the system. Descriptive analysis is conducted on the data collected from 29 representative farms, from 10 Tehsils of four districts of rice-wheat in Punjab having 1-68 ha farm size selected through purposive random sampling applying typical farm methodology. Rice is cultivated on 87% and fodder on 8% of the total area during *kharif* while wheat on 75% along with berseem on 14% of total area during *rabi* season. Almost 81% rice and more than 50 % wheat is harvested with combine followed by burning of residues that not only create environmental pollution but also affect the productivity of the cropping system. Stagnation in yield of rice and wheat is reported mainly due to uninterrupted sequential rice-wheat cropping which cause low fertility, increased weed problem, more disease and insect invasion leading to yield losses. Berseem is the only crop that breaks this rotation. Farmers are aware of the beneficial effects of this crop rotation and believed that this rice-berseem rotation control weeds in the next wheat crop along with yield improvement of both rice (upto 5.4 md acre^{-1}) and wheat (4.4 md acre^{-1}). However there is need to assess the economic impact and evaluation of berseem in rice-wheat cropping system and evaluation of different wheat planting techniques in relation with residue management. These techniques may include farmer practice (partial burning, land preparation and broadcast); partial burning zero tillage ; Farm Machinary Institute seeder (planting with in the residue).

Key Words: Rice-Wheat; Berseem; Typical Farm; Productivity; Yield; Yield Components; Pakistan.

INTRODUCTION

The rice-wheat system is one of the important and largest agricultural production systems in South Asia covering 13.5 mha and about 1.3 billion or about 20% of the world population is dependent on the produce of this area (Timsina and Connor, 2001, Ladha et al., 2000). The rice-wheat system is primarily irrigated and its 85% lies in the Indo-Gangetic Plains, encompassing Northern India, Pakistan, Nepal and Bangladesh and covering about 32% of the total rice area and 42% of the total wheat area in these four countries and accounted for between 1/4th and 1/3rd of total rice and wheat

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production in these countries (Timsina and Connor, 2001; Hobbs and Morris, 1996).

Rice-wheat cropping is among the most extensive systems in Pakistan, covering 2.1 mha and nearly three-fifth of this area falls in the Punjab province (GoP, 2003). The rice-wheat area of Punjab mainly covers Gujranwala, Sheikhupura, and Sialkot Districts with some parts of Gujrat and Lahore Districts as well. Typically *Kallar* belt is the genuine homeland of the 'Basmati' rice, a cause of fame to Pakistan. The pleasant and sweet fragrant Basmati rice, a speciality of Pakistani Punjab, has the quality of elongation when cooked and the fluffiness that makes it unique in the world (Sheikh and Abbas, 2007). Punjab's rice-wheat cropping system plays a key role in ensuring national food security and remained centered to many research and development activities.

However, the yields of these crops are not increasing with same pace as in earlier years (Mann and Garrity, 1994). There is a substantial gap between actual and potential wheat yields in Pakistan's rice-wheat systems (Byerlee et al., 1984 and Sheikh et al., 2000). Similarly factors responsible for low productivity in the rice wheat system were diagnosed by many other researchers including yield losses due to delayed wheat planting after rice and high costs of seedbed preparation following rice (Randhawaha, 1979; Hamid et al., 1987; Hobbs, 1985; Zia et al., 1992; CGPRT, 2003), low soil fertility is the common problem along with swarming insect and weed infestation (Sheikh and Abbas, 2007). A special problem in agronomic management as rice requires puddled soils to maintain submergence during the growing season while wheat grows best in well-drained soils, which allow deep penetration of the root system (Hobbs et al., 1987). Rice yields are also stagnated despite steadily increasing dosages of fertilizers (Amir, 1985).

Evidences from some long-term experiments show that problems of stagnating yields and even yield declines are occurring in the rice-wheat system of South Asia (Regmi et al., 2002; Duxbury et al., 2000). Total factor productivity is declining and farmers have to apply more fertilizer to obtain the same yields (Hobbs and Morris, 1996; Murgai et al., 2001). The present intensive cropping of the rice-wheat system in vogue was not the tradition, instead one crop a year was cultivated. About three decades ago rice-wheat sequential cropping system began to take-off. With short duration varieties, synthetic fertilizers and tubewell installation for irrigation made it possible to grow two crops in a year (Sheikh and Abbas, 2007). The continuous sequential cropping has observed problem of stagnation of the rice-wheat productivity in many countries.

Present study has therefore, been planned to assess the present status, farmers practices and their perception to incorporate the traditional knowledge in the future project planning for developing a sustainable and economically viable cropping system for rice wheat cropping system of Punjab. The findings would be the basis of future trials which would be suggested to improve wheat productivity in rice-wheat cropping system.

MATERIALS AND METHOD

A reconnaissance survey of the farmers was conducted in the rice-wheat area of Punjab. Four districts namely Gujranwala, Hafizabad, Sheikhupura and Sialkot were selected as major rotation followed here is rice -wheat. Most of the area is irrigated; however, it also receives 425-800 mm rainfall .

In the survey districts, rice is cultivated on 0.7 mha. Basmati rice occupies 73% of the area and rest is under non-Basmati varieties. Average Basmati and non-Basmati rice yields are 1.84 and 2.38 tha^{-1} respectively (Table 1). In this area, wheat is cultivated on more than 0.85 mha with total production of 2.3 mt in 2010-11. Average wheat grain yield was 2.5 - 3.2 tha^{-1} in different districts (Government of Punjab, 2011). Wheat grain yields are generally lower than other irrigated districts of the Punjab (Table 2).

Table 1. Basmati and non-Basmati rice production in survey districts during 2010

	Area(ha)		Production (t)		Yield(tha)[1]	
District	Bas.	Non-Bas.	Bas.	Non-Bas.	Bas.	Non-Bas.
Sheikhupura	176800	23200	289860	48100	1.64	2.07
Sialkot	132000	20400	264690	47490	2.01	2.33
Gujranwala	137200	101200	257070	250240	1.87	2.47
Hafizabad	78400	47200	151870	110860	1.94	2.35
Total / Mean	524400	192000	963490	456690	1.84	2.38

Source: Government of Punjab 2011 www.agripunjab.gov.pk).

Table 2. Wheat production in survey districts during 2010-11

District	Area (ha)	Production (t)	Yield (tha^{-1})
Sheikhupura	221360	581870	2.63
Sialkot	203960	515920	2.53
Gujranwala	231070	744910	3.22
Hafizabad	159440	458190	2.87
Total / Mean	815830	2300890	2.82

Source: Government of Punjab 2011 www.agripunjab.gov.pk

During the field visit 29 farmers were contacted. Alongwith the farm resources and land allocation to main crops, the issues of the sequential rice-wheat rotation alongwith perception of farmers on the effect of berseem plantation in the system were recorded. Survey was conducted by an agronomist of Wheat Programme and a social scientist from Social Sciences Institute of NARC, Islamabad during April 23-27, 2011. Local extension agents were also involved to identify the representative farms in each area.

Methodology applied for sample selection was developed by International Farm Comparison Network and utilizes the concept of typical farms. Farm types are determined on the basis of the knowledge of regional dairy experts (Hemme et al., 2004; Garcia et al., 2003). The first (small) farm type in this study has been defined in a way to represent the size that is close to the statistical average in the study area. The other 'typical' farms represent larger farm types and illustrate economies of scale or exemplify a different production system (Hemme et al., 2004). In rice-wheat area of Punjab, typical farms were defined by the criteria (a) crop rotation, (b) farm size and (c) location to cover all farm types that are important in land allocation and number of households having different landholding. This methodology helps to do synthesis of large area with small sample size selected on the basis of experts' background knowledge and long interaction with the target communities. Hence is most cost effective and time saving.

Following typical farm

methodology, purposive random sampling was used mainly to include all the rice-wheat area with some variation in the crop rotation and farm size. Therefore the spread of the selected area was large mainly to cover all these areas. Therefore the farmers were selected from about 10 Tehsils of the selected districts including Daska, Ferozwala, Gujranwala, Hafizabad, Kamonkay, Muridkey, Pasroor, Sambrial, Sialkot and Wazirabad.

Data was collected using a standard questionnaire. Detail information was collected on the farm size, area allocation to rice-wheat and berseem, rice and wheat management alongwith residue management, sowing and harvesting methods and the farmer's perception about potential benefits of incorporation of berseem in the rice- wheat rotation.

RESULTS AND DISCUSSION

Land Holding

The average land holding of the selected farmers was 10-15 ha. Although the sample was small yet it covers all the farm sizes and the surveyed farms have 1-68 ha area. Out of 29 surveyed farms, two farms had more than 40 ha area; three farms were in the range of 20-40 ha; 6 farms 10-20 ha; 8 farms in the range of 10-20 ha and 10 farms were in the range of 1-10 ha.

Soils Types

Majority of the farms have clay loamy and loamy soil with good drainage conditions that are known as *halki* and *bhari mehra* in farmer terminology. However, the farms had clayey soils with moderate to poor drainage known as *rohi mehra*. Salinity was also a problem on some farms and these soils are known as kalar soils and lower wheat productivity. Clay loam was the main soil type representing more than half of the sample farms area followed by saline sandy and clayey.

Table 3. Soil type by district at sample farms (% Farmers)

Soil type	Gujranwala	Hafizabad	Sheikhupura	Sialkot	Overall
Clay loam	66.7	57.1	41.2	60.0	53.5
Sandy	0.0	14.3	11.8	0.0	7.0
Saline sandy loam	0.0	0.0	5.9	0.0	2.3
Saline Sandy	11.1	14.3	23.5	20.0	18.6
Clayey	11.1	14.3	17.6	20.0	16.3
Sandy loam	11.1	0.0	0.0	0.0	2.3

Cropping System

Rice is cultivated on 87% followed by fodder on 8% of the total area during kharif season. Almost all of the farmers are growing Super Basmati on 70- 80% area. However, Basmati-386 is grown on 20-30% of the farm area. In rabi season, wheat is planted on 75% of total farm area, followed by berseem on 14% area in this region of the Punjab (Table 4). Wheat after Super Basmati is the dominant crop rotation, followed by wheat after Basmati-386. Other rotation on significant area includes Berseem Rice Wheat. In small pockets, other cropping systems being practice include:

i. Rice 386-Berseem-Jawar-Wheat
ii. Rice 386-Berseem-Hybrid maize-wheat
iii. Rice 386-Peas-Hybrid maize
iv. Rice-Peas-Sunflower

Table 4. Percent area allocated to wheat, rice and berseem

District	Wheat	Berseem	Rice
Gujranwala	87	13	89
Sheikhupura	71	20	94
Hafizabad	74	9	77
Total	75	14	87

Rice Harvesting and Residue Management

Almost 80% of the rice crop is harvested with combine harvester, however, remaining 20% is being hand harvested. Burning of the residue in combine-harvested fields is the most prevalent method for residue management in the region. Burning of the residue is not only dangerous for environment but also bad for sustainability of rice-wheat cropping system. Generally, loose residue that is burnt is known as partial burning. Burning results in air pollution and release of carbon dioxide, with significant loss of organic matter and nutrients. In contrary, farmers think that burning reduces weeds in the farms and results in reduced tillage operations for incorporation of leftover residue in the soil. Harvesting of 81% rice area was done by combine harvester and residues were burnt on the same area.

Land Preparation

Seedbed preparation for wheat crop in these combine harvested and burnt fields involves intensive tillage. Residue is incorporated and chopped with the help of three disking and three plowing with planking on average (Table 5). Use of 1-2 rotavator in 5 farms was also reported that reduced number of disking and plowing in these fields. Depending upon field condition and amount of residue, 1-4 disking and 2-6 plowing operation are done.

Table 5. Average operations for land preparation

District	Disking	Cultivator	Rotavator
Gujranwala	3.29	2.86	0.14
Sheikhupura	2.73	2.73	0.36
Sialkot	2.71	2.14	0.14
Hafizabad	2.75	2.75	0.00
Overall	2.86	2.62	0.21

Wheat Variety

Most of the farmers are planting wheat variety Sehar-06, followed by Wattan, Faisalabad-08, Auqab-2000 and Lasani. Few farmers still plant old wheat variety Inqalab-91. According to survey, wheat variety Sehar-06 was reported at 22 farms, Wattan on five farms, Faisalabad-08, Auqab-2000 and Lasani-08 on 2 farms.

Planting Time

Super Basmati fields are cleared late and require intensive tillage for residue management, so wheat planting is done from November 25 to December 15, and even in some cases wheat planting goes to end December. Wheat is planted late on 70% area. Timely planting of wheat is only possible on the fields that are planted after Basmati-386. Wheat planting after Basmati-386 is completed during November 05-30 in 30% region. These rice fields are harvested in September and require pre -irrigation for wheat planting. Less amount of tillage is required for their preparation and subsequently planted before November 20. These

fields are as good as fallow fields and their yield is better than the Super Basmati cleared field.

Fertilizer Management

In the survey area, majority of the farmers use 63 $kgha^{-1}$ of phosphorus and 96 $kgha^{-1}$ of nitrogen for wheat. Phosphorus fertilizer alongwith nitrogen in the form of diammonium phosphate (DAP) is used at planting and around 40 $kgha^{-1}$ nitrogen in the form of Urea is applied with irrigation to wheat crop. Generally, farmers are using 1-2 bags $acre^{-1}$ of DAP at planting. Some farmers used 1-2 bags $acre^{-1}$ of Nitrophos (1-2) and one farmer reported SSP usage at planting. During early wheat growth period, 1-2 bags of urea per acre is being applied with first irrigation. The average fertilizer use in study area is ascertained (Table 6).

Table 6. Fertilizer used in wheat by districts in sample area

(Bags $acre^{-1}$)

District	Basal DAP	Basal Nitrophos	Post Urea
Gujranwala	1.14	0.00	1.50
Sheikhupura	1.05	0.27	1.41
Sialkot	0.86	0.00	1.21
Hafizabad	1.38	0.00	2.13
Overall	1.07	0.10	1.48

Planting Method and Seed Rate

Wheat is planted on major area through broadcasting followed by plowing and planking of the field. Different seed rates were used in different areas of rice-wheat (Table 7). Only three big farmers from 29 reported to use Rabi drill partially in this region. When questioned regarding zero tillage (ZT), one farmer reported to have used ZT during this season on 10 acres in Wazirabad and many have used this year. Some farmers used ZT drill before but not using it since 2006. They found it fit for clayey soils that are poorly drained. Almost all of this planting of wheat with drill was done in partially residue burnt fields. At present no planter with capacity to plant in residue is available in field, so even the willing farmers have no choice in this regard.

Table 7. Wheat seed rate in the study area

District	Seed rate ($kgha^{-1}$)
Gujranwala	122
Sheikhupura	119
Sialkot	124
Hafizabad	117
Overall	120

Irrigation Management

All of the wheat planted after Super Basmati is with residual moisture (*wadwatter)* and 2.4 irrigation applied during the growing season with the range of 1-3 during the season. Wheat after Basmati-386 is planted after pre irrigation and 3-4 irrigatios are applied during the growth period. Number of irrigations applied, during growing season vary from 1-4 depending upon amount of rainfall, drainage conditions and soil type. In general, three irrigations are applied to sandy and clay loam, whereas, 1-2 irrigations are applied to clayey soil with poor drainage. On an average 2.38 irrigations were applied to wheat (Table 8).

Table 8. Irrigation for wheat at sample farms

District	Irrigation No.
Gujranwala	2.79
Sheikhupura	2.18
Sialkot	2.00
Hafizabad	2.88
Overall	2.38

Weeds and their Control

Weed infestation is one of the important factors that affect wheat productivity in this region. The most prevalent weed in the wheat field is Dumbi Siti (Phalaris minor) that have a considerable effect on wheat yield. Broadleaf weed like Bathu, Senji and Mattri are also found in the area. All of the farmers in this region are using herbicides for the control of weeds. Majority of the farmers (57%) reported Dumbi Siti followed by Batho by 25% farmers and Mena Matter by 11% farmers in wheat. The other two weed Leh and Senji was reported by 7% only in Sheikhupura while Senji was reported by 10% and 14% farmers in Gujranwala and Hafizabad only (Table 9).

Table 9. Weed reported by the sample farmers (% response)

Weed	Gujranwala	Hafizabad	Sheikhupura	Sialkot	Overall
Dumbi siti	60	43	60	58	57
Batho	20	29	20	33	25
Mena mattri	10	14	13	8	11
Leh	0	0	7	0	2
Senji	10	14	0	0	5

Harvesting

Wheat harvesting has mechanized largely in this region. About half of the wheat area is harvested through combine harvester; however, rest of the wheat is harvested by hand and reaper and threshed by threshers (Table 10). Because of significant economic value, collection of *bhoosa* from combine harvested fields through wheat straw choppers is gaining momentum. Due to this reason, burning of wheat residue is restricted to less than around 50% of the area.

Table 10. Wheat harvesting method at sample farms

(% area harvested)

District	Combine	Manual/Reaper
Gujranwala	62	38
Sheikhupura	38	62
Sialkot	56	44
Hafizabad	80	20
Overall	54	46

Wheat Productivity

Wheat yield after Super Basmati ranged from 3.08 to 3.98 tha^{-1} with an average of 3.4 tha^{-1} while after rice-386 it ranged from 2.20 to 4.50 tha^{-1} with an average of 3.78 tha^{-1} (Table 11).

Table 11. Wheat yield at sample farms

(tha^{-1})

District	Wheat after Super Basmati	Wheat after Rice-386
Gujranwala	3.98	4.50
Sheikhupura	3.08	3.95
Sialkot	3.33	2.20
Hafizabad	3.25	--
Overall	3.40	3.78

Productivity difference with respect to soil type was also explored. Average wheat grain yield in timely planted wheat on loamy soils with better drainage was upto 5.0 tha^{-1}, whereas, 3.5 tha^{-1} wheat grain yield was reported in late planted wheat

after Super Basmati. Wheat planted on clayey soils and saline area yielded 1.4-3.0 tha^{-1}.

Super Basmati average yield is 3.5 tha^{-1}, however average Basmati-386 yield is 5.0 tha^{-1}. Almost all of the farmers are growing Super Basmati on farms and its area ranged between 50 and 100 % of the rice area at individual farm. However, Basmati-386 is grown on 20-30% area.

Table 12. Rice yield at sample farms

(tha^{-1})

District	Super Basmati	Rice-386
Gujranwala	4.00	5.70
Sheikhupura	3.29	4.67
Sialkot	3.51	_
Hafizabad	3.75	5.15
Overall	3.56	5.11

Rice Harvesting Method

Harvesting of rice is mainly mechanized in rice-wheat area of Punjab. Almost all area of super basmati is harvested through combine while Basmati-386 is mainly harvested manually . Overall 81% rice area is harvested through combine in the study area while remaining 19% is manually harvested. More use of combine was found in Sheikhupura and Sialkot where 90% area is harvested through combine (Table 13).

Table 13. Rice harvesting method at sample farms

(% area)

District	Combine	Manual
Gujranwala	83	17
Sheikhupura	72	28
Sialkot	90	10
Hafizabad	90	10
Overall	81	19

Residue Management

Use of combine for harvesting of wheat and rice has posed serious problem of burning of residue of the crops. Residue burning was more in rice mainly due to less time for land preparation for wheat while it was less in the wheat field harvested with combine (Table 14).

Table 14. Residue burning in rice and wheat after combine harvesting

(% area)

District	Rice	Wheat
Gujranwala	83	62
Sheikhupura	72	29
Sialkot	90	56
Hafizabad	90	80
Overall	81	51

Berseem in Rice-Wheat Crop Rotation

The rice-berseem-rice rotation is important in the rice belt of Punjab and KPK provinces being multipurpose in nature. Besides being a valuable fodder, berseem also improves soil fertility and suppresses weeds and thus acts as an excellent means of weed control for subsequent rice and wheat crops (Haqqani et al., 2000) .

Sheikh and Abbas (2007) have reported that rice-wheat sequential cropping system was prevalent in the entire study area. The farmers perceived that uninterrupted sequential cropping cause low fertility, increased weed problem, more disease and insect invasion leading to yield losses. They intend to break the rice-wheat rotation but according to them options are less although some farmers broke rotations to reduce losses. The period

of rotation break averaged about 6 years. The real break crops were fodders (berseem/oats). Small farmers were the major change agents in breaking the rice-wheat sequence. They rotated their field with fodder necessary for their livestock. Small farmers followed shorter period to change a rotation whereas large farmers take longer period to change. Most of the large farmers, who followed rice-wheat rotations, were not able to break the rotation in an appropriate period even if they intended to do so.

At present berseem is planted on 14% area and this rotation is second after rice-wheat. During the survey it was found that berseem is planted in weaker field mainly to improve fertility of land. The second priority is that berseem as fodder should be close to the farmhouse and almost every farmer is following this crop rotation. Berseem is rotated on close to farmhouse fields to save irrigation water, ease in fodder cutting and transportation.

Farmers have allocated area to berseem from 0.5-10 acre and that was linked with number of animals and village proximity to urban center and on an average rotation was completed in 2 - 3 years. It is not possible for farmers to adopt this rotation on fragmented land or far off fields. Berseem is preferably cultivated after Basmati- 386 rice.

In one growing season, 4-5 cuttings with seed are obtained by the farmers. Berseem needs more irrigation than wheat during growing season. The average gross income from berseem crop was ranged between Rs. 40000 and Rs. 45000 per acre.

Benefits of Berseem Based Rotation

The effect of berseem based rotation on yield of following crops after berseem and effect on weed control was investigated from the farmers. Farmers were very clear about its advantages in yield and weed control for following rice and wheat crop at berseem fields. All farmers think that on an average rice yield was improved up to 5.4 mds $acre^{-1}$ and wheat yield improvement was 4.4 mds $acre^{-1}$. No effect on weeds in rice was observed by the farmers. However, in wheat the weed infestation was reduced to an extent that farmers had not to apply any herbicide.

In addition to these benefits the fertility improvement was reported as 9 out of 29 farmers reported that they reduced 50% urea fertilizer application (one bag of urea per acre) for rice crop. While in wheat, no fertilizer saving is reported.

Table 15. Effect of berseem on following rice and wheat yield

(mds $acre^{-1}$)

District	Additional rice yield after berseem	Additional wheat yield after berseem
Gujranwala	6.86 ± 2.47	5.29 ± 2.43
Sheikhupura	4.09 ± 2.25	3.09 ± 2.25
Sialkot	5.57 ± 3.69	5.00 ± 3.83
Hafizabad	6.00 ± 3.36	5.50 ± 1.29
Overall	5.38 ± 2.29	4.41 ± 2.27

It can therefore be concluded that there is need to assess the economic impact and evaluation of berseem in rice-wheat cropping system that may have positive effect

on following rice and wheat productivity through effect on soil fertility improvement and winter weed control. Berseem cannot be planted on large scale due to its low requirement and cannot replace wheat due to food security and market factors. Hence there is need to educate farmers for adoption of rice-berseem rotation on different plots each year so that berseem is practiced at each plot of the farm overtime. The other important issue is the residue management for which evaluation of different wheat planting techniques in relation with residue management needs to be studied. These techniques may include farmer practice (partial burning, land preparation and broadcast); partial burning zero tillage; Farm Machinery Institute seeder (planting within the residue).

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