

## Enhancement of Wheat Productivity as a Relay Crop in Cotton-Wheat Cropping System

Hafiz Muhammad Nasrullah<sup>1</sup>, Abdul Rashid Zahid<sup>1</sup>, Muhammad Akhtar<sup>4</sup>, Abdul Majid<sup>3</sup>, Basharat Ali<sup>1</sup>, Haseeb-ur-Rehman<sup>5</sup>, Javaiz Alam<sup>5</sup>, Muhammad Imran Akram<sup>2</sup>, Hamid Nawaz<sup>5,\*</sup>

<sup>1</sup>Agronomic Research Station, Bahawalpur, Punjab, Pakistan

<sup>2</sup>Agricultural Research Station, Bahawalpur, Punjab, Pakistan

<sup>3</sup>ICARDA, National Agricultural Research Centre, Islamabad, Pakistan

<sup>4</sup>Sugarcane Sub-Station, Bahawalpur, Pakistan

<sup>5</sup>Department of Agronomy, Bahauddin Zakariya University (BZU), Multan, Pakistan

### Edited by:

Fahd Rasul,  
University of Agriculture,  
Faisalabad, Pakistan

### Reviewed by:

M. Qasim Shahid,  
South China Agricultural  
University, Guangzhou,  
China

M. Aown Sammar Raza,  
The Islamia University,  
Bahawalpur, Pakistan

Imran Haider Khan,  
Nanjing Agricultural  
University, Nanjing, China

### Received

June 18, 2017

### Accepted

December 25, 2017

### Published Online

December 30, 2017

**Abstract:** Under the sudden climatic change, wheat yield after cotton harvest is suffering in cotton-wheat cropping system of Southern Punjab, Pakistan. Introduction of Bt cotton in the wheat-cotton cropping system caused the sowing and harvesting time confliction. Therefore, the study was conducted at different locations in the field during consecutive two years 2011-2012 and 2012-2013 at Bahawalpur, Pakistan. The sowing of wheat was delayed by 19-39 days under conventional sowing as compared to relay sowing of wheat in standing cotton. The additional one picking was an extra benefit in relay sowing of wheat in terms of seed cotton yield and ultimately economic benefit to the farmer. The increase in wheat yield under relay seeding of wheat was primarily due to healthy spike production and maximum numbers of grains spike<sup>-1</sup>. Wheat sown with relay seeding was obtained higher yield (38.5%), fertile tillers (30.7%), grains spike<sup>-1</sup>(38.5%) and 1000-grain weight (26.8%) in contrast to farmer practice. Benefit cost ratio proved that farmers can obtain maximum economic benefit with increase in yield (29.39%) by adopting the newly emerged method for wheat sowing as a relay crop in the standing cotton crop.

**Keywords:** Cotton, cropping system, relay cropping and wheat.

**Corresponding author:** Hamid Nawaz, E-mail:[hamybhatti@gmail.com](mailto:hamybhatti@gmail.com)

**Cite this article as:** Nasrullah, H.M., A.R. Zahid, M. Akhtar, A. Majid, B. Ali, Haseeb-ur-Rehman, J. Alam, M.I. Akram and H. Nawaz. 2017. **Enhancement of Wheat Productivity as a Relay Crop in Cotton-Wheat Cropping System.**Journal of Environmental and Agricultural Sciences. 13: 25-30.



Copyright © Nasrullah et al., 2017

This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium provided the original author and source are properly cited and credited.

## 1. Introduction

Population of Pakistan has surpassed 193 million by 2016, where most of people like bread of wheat to eat (World Bank, 2017). Therefore wheat (*Triticum aestivum* L.) is the staple diet of the peoples and important food grain in Pakistan for making agricultural policies. Wheat contributes 3.1% to GDP and 14.4 % to value addition in agriculture (Government of Pakistan, 2013). Pakistan, like many other developing countries, has an agrarian based economy. The agriculture sector contributes 21.4 % to GDP and employs 45 percent of the country's labor force and contributes in the growth of other sectors of the economy and absorbs poverty and the transforming towards industrialization (Government of Pakistan, 2013). The low productivity of wheat crop in cotton wheat cropping zone is attributed to its very late sowing after harvest of cotton (Rehmani et

al., 2016). Cotton is the most important cash crop of Pakistan contributing largest share in export revenues. Moreover, lint, oil extraction and preparation of meal (from cotton seeds) supply 80% of the national oil seed production (Rehman et al., 2015; Rehman et al., 2018; Ullah et al., 2016).

Early picking of cotton for timely sowing of wheat crop seems very tough (Ahmad et al., 2016; Government of Pakistan, 2004). With the increase in population the demand for food and fiber is also increasing rapidly (Conijn et al., 2018; Long et al., 2015). To avoid loss in cash crop and timely sowing of next crop relay cropping is potential solution (Du et al., 2015; Zhang et al., 2007; Zhang et al., 2008). Relay cropping is widely used in different countries and cropping systems to solve issues related to inefficient utilization of available resources, conflicting sowing time, fertilizer application, and

soil degradation with aim of higher crop productivity and without compromising sustainability (Huang et al., 2017; Mao et al., 2014; Tanveer et al., 2017; Vrignon-Brenas et al., 2016a; Vrignon-Brenas et al., 2016b; Vrignon-Brenas et al., 2016c; Zhou et al., 2015; Zhou et al., 2014). In cotton-wheat cropping system net benefit of relay cropping is comparable with the sowing of wheat after harvesting of cotton (Sajjad et al., 2018; Singh et al., 2017; Yadvinder et al., 2014). Conventional sowing of wheat after cotton harvest resulted decreased yield as compared to sowing of wheat in standing cotton, gave higher yield (Bange, and Milroy 2001; Shah et al., 2016).

In conventional sowing methods, i.e. wheat is sown after harvest of cotton gave lesser yield as compared to wheat relayed in standing cotton (Khan and Khaliq, 2005). The sowing of wheat is generally delayed due to subsequent pickings and late harvesting of cotton and land preparation for sowing of wheat (Feng et al., 2017). Relay cropping the possible option for early planting of wheat in standing cotton in wheat cotton based cropping system. The wheat yield increased in relay cropping may be due to more number of grains per spike and higher spike density (Butter et al., 2013). However, in current studies new relay cropping methods are needed on cotton based cropping systems and their effect on agro-physiology of crops. The objectives of this study were to determine the production potential and economics of cotton-based relay cropping of wheat.

## 2. Materials and Methods

The experiment was planned for two years at different locations on farmer's field. i.e., during years 2011-2012 and 2012-2013. Details of date of sowing under conventional and relay sowing are described in

Table 1. Main experimental plot was split in to two sub-plots i.e. one wheat sown as relay crop in standing cotton, whereas in second sub-plot wheat was sown after the harvest of cotton. Wheat (*Triticum aestivum* L.) crop was sown in standing cotton and plot was irrigated to the depth of 7.5 cm. Wheat variety Mehraj-08 was sown on November, 10 to 20 in standing cotton with zero-tilled soil. In this study innovative technique sowing of wheat in standing cotton was compared with the farmer practice. Farmer practice includes the last picking of cotton in December, removal of cotton sticks, land preparation with heavy tillage and planting of wheat through broadcast. In relay cropping wheat seed was soaked in water tank for 5 to 6 hours and put in open air for further 5 to 6 hours for processing. In relay cropping wheat seed was broadcast in standing cotton after irrigation in early November. After the last picking of cotton, sticks of cotton were cut manually from the field during December.

All potassium and phosphatic fertilizers ( $P_2O_5$  and  $K_2O$ ) along with half N were given after removal of cotton sticks with 1<sup>st</sup> post planting irrigation. The remaining N was given during mid-January. Recommended weedicides were applied to control the weeds from the said crop. The zero-tilled seed bed and normal seed rate was used for relay cropping system. However, the supply of moisture was continued for adequate germination and crop stand. The crop was harvested at its physiological maturity. The observation like fertile tillers per unit area, grains spike<sup>-1</sup>, 1000- grain weight, grain yield (kg ha<sup>-1</sup>) were observed for estimating the economic benefits of relaying. The statistical analysis was conducted by using Statistix 10 as described earlier (Nawaz et al., 2017).

**Table 1. Time of wheat sowing for relay and conventional cropping**

Treatment	Farmer Name and Location	Sowing Date of wheat		Difference in sowing (days)
		Relay Cropping	Conventional cropping	
<b>2011-12</b>				
L <sub>1</sub>	Muhammad Islam 6BC, BWP	04.11.2011	10.12.2011	36
L <sub>2</sub>	Muhammad Aslam, Samasatha, BWP.	11.11.2011	05.12.2011	24
L <sub>3</sub>	Haji Abdul Ghafar, Hoot Wala, BWP	08.11.2011	04.12.2011	26
L <sub>4</sub>	Tasawar Hussain, Rajapur, Lodhran	14.11.2011	23.12.2011	39
L <sub>5</sub>	Shafiq Farm Basti Reddan, BWP.	12.11.2011	30.11.2011	30
<b>2012-2013</b>				
L <sub>1</sub>	Muhammad Islam 6BC, BWP	12.11.2012	24.11.2012	12
L <sub>2</sub>	Muhammad Aslam, Samasatha, BWP.	18.11.2012	08.12.2012	20
L <sub>3</sub>	Haji Abdul Ghafar, Hoot Wala, BEP	16.11.2012	14.12.2012	28
L <sub>4</sub>	Tasawar Hussain, Rajapur, Lodhran	19.11.2012	08.12.2012	19
L <sub>5</sub>	Shafiq Farm Basti Reddan, BWP.	10.11.2012	08.12.2012	28

L, location; BWP, Bahawalpur

**Table 2. Response of wheat yield and yield components under conventional and relay cropping at different experimental sites**

Location	Yield (kg ha <sup>-1</sup> )		Change (%)	Tillers (m <sup>-2</sup> )		Change (%)	Grains spike <sup>-1</sup>		Change (%)	1000-GW (g)		Change (%)
	RS	CS		RS	CS		RS	CS		RS	CS	
L <sub>1</sub>	5275	3476	34	414	306	26	52	32	38	48	35	27
L <sub>2</sub>	5533	3398	39	406	354	13	51	37	27	38	35	09
L <sub>3</sub>	4968	2950	41	411	296	28	48	31	35	43	33	23
L <sub>4</sub>	4891	2891	41	424	250	41	51	29	43	43	27	37
L <sub>5</sub>	5167	3179	38	430	240	44	56	31	45	52	32	38
<b>Mean</b>	5166 A	3178 B	38.5	417 A	289 B	30.7	52 A	32 B	38.5	45 A	32.4 B	26.8
LSD	353.7			49.5			7.3			6.2		

Means not sharing the same letters in a group differ significantly at 5% probability level. Each value is average of six values taken in two experimental years (2011-12 and 2012-13). RS, Relay Sowing; CS, conventional sowing; GW, grain weight.

### 3. Results and Discussion

#### 3.1 Fertile Tillers

The results of study showed that significantly greater number of fertile tillers (417 m<sup>-2</sup>) was observed in wheat relayed in standing cotton compared to farmer practice of sowing wheat after the harvesting of cotton (289 m<sup>-2</sup>) (Table 2). The fertile tillers (m<sup>-2</sup>) in wheat sown after harvest of cotton reduced by about (44.3%) that might be due to temperature variations in 10<sup>th</sup> November to 31<sup>st</sup> December and late sowing of wheat. Shoot meristem growth is linearly correlated with the temperature and initiation of shoot (Ong and Barker 1985).

The stages of development of wheat were delayed due to late sowing of wheat after the harvesting of cotton. Similar results also reported by Kirby and Ellis (1980) that number of tillers reduced due to late emergence of leaf and decreased length of leaf initiation due to late sowing of wheat. Sowing dates significantly affected fertile tillers m<sup>-2</sup>, number of grains per spike and grain yield kg ha<sup>-1</sup> (Aslam et al., 2013; Nayyar et al., 1992).

#### 3.2 Grains Spike<sup>-1</sup>

Wheat relayed in cotton produced 38.5% higher number of grains spike<sup>-1</sup> as compared to wheat sown

subsequent to harvesting of cotton (Table 2). The number of grains per spike increased because of appropriate time availability for grain formation and suitable temperature at anthesis stage in case of relay sowing of wheat compared to farmer's practice of late sown wheat in December after complete removal of cotton sticks from the field and land preparation. So, more grains per spike (52) were observed in relay sowing of wheat in standing cotton than the farmer's practice of late sown wheat (32) subsequent to harvesting of cotton and preparatory tillage. These results are comparable with that Kirby (1969) and Noworolnik (1989).

During the study statistically similar trends of grains per spike were observed for both years. The higher temperature at anthesis and grain formation stage resulted in fewer number of grains per spike in case of late sown wheat in farmer's practice compared to relayed sowing of wheat in standing cotton that may be due to less time for grain development. In case of relay sowing of wheat appropriate time is available for all the growth stages of development to wheat crop resulted in better number of grains per spike. The late sowing of wheat crop has negative influence on growth and number of grains per spike (Aslam et al., 2013; Jan et al., 2000).

**Table 3. Benefit Cost Ratio (BCR) analysis of conventional and relay sowing of wheat and cotton**

Sowing Methods	Wheat yield (kg ha <sup>-1</sup> )	Cotton yield (kg ha <sup>-1</sup> )	Gross income (Rs. ha <sup>-1</sup> )			Cost variation (Rs. ha <sup>-1</sup> )	Net Income (Rs. ha <sup>-1</sup> )
			Wheat	Cotton	Total		
CS	3178	2734	103285	170875	274160	12300	261860
RS	5166	3275	167895	204688	372583	1750	370833
<b>Increase in RS</b>	1988	541	64610	33813	98423	10550	108973
<b>% increase in RS</b>	38%	16%	62%	20%	36%	86%	42%

Data is average of independent values taken from experiment conducted in triplicate at five experimental sites in two experimental years (3×5×2). CS, conventional sowing; RS, relay sowing.

### 3.3 1000-Grain Weight

The results of the study showed that relay sowing of wheat significantly gave 26.8% more 1000-grain weight compared farmer practice late sown wheat (Table 2). The reason behind this is the longer time period available at grain filling stage in case of timely sowing of wheat. The grain weight was decreased by about ten percent in case of late sowing of wheat (Green et al., 1985). Many scientists reported that 1000-grain weight significantly affected by late sowing of wheat (Jan et al., 2000). Various studies reported significant impact of crop sowing time on 1000-grain weight (Aslam et al., 2013; Tahir et al., 2009)

### 3.4 Grain Yield

The results of the study showed that higher grain yield (5166 kg ha<sup>-1</sup>) was recorded in wheat sown in standing cotton compared to farmer's practice (3178 kg ha<sup>-1</sup>) of sowing wheat after removal of sticks from the field and land preparation (Table 2). The increased grain yield (38.5%) of wheat may be due to 30.7% more fertile tillers, 38.5% more grains per spike and 26.8% more 1000-grain weight in relayed cropping of wheat in cotton compared to farmer's practice after preparatory tillage (Table 2).

The wheat crop sown in standing cotton gets favorable temperature for germination, growth and grain development. The wheat crop sown after the preparatory tillage not only faced the unfavorable temperature but also get short time period of about 1.5 month for total crop growth duration. Overall, the performance of late sown wheat was affected by all the yield dependent factors.

These results are in line with the findings of earlier reports (Akkaya and Akten, 1989; Andrew et al., 1990; Aslam et al., 2013; Piech and Stankowski, 1989; Stapper and Fischer, 1990;). Tahir et al., (2009) observed that sowing times significantly affected the grain yield. The maximum grain yield of wheat was observed when sown on October (Zia-ul-Hassan et al., 2014). The decreased in yield of wheat can be attributed to the unfavorable temperature regimes at all the developmental stages of growth.

### 3.10. Benefit Cost Ratio (BCR)

Wheat sown in standing cotton produced 38 % (5166 kg ha<sup>-1</sup>) more wheat compared to farmer's practice of sowing wheat after preparatory tillage and removal of sticks from field. Farmer obtained extra economic advantages (Rs. 0.1 million ha<sup>-1</sup>) through adopting relay sowing of wheat in standing cotton. In addition, the land preparation cost that approximately

amounts to be twelve thousands rupees is also saved by relay cropping of wheat in comparison to farmer's practice of planting wheat after cotton harvesting. Furthermore, the cotton crop yield is also increased by about 16 % by picking the matured bolls up to mid-December that gives monetary benefit to the grower (Table 3).

### 4. Conclusion

The ease of adopting the relay cropping of wheat (i.e. no preparatory cost, not any additional resources required neither any special equipment needed nor any extra labor etc.) is another merit of this technology. In addition, the land preparation cost that approximately amounts to be twelve thousands rupees is also saved by relay cropping of wheat as compared to conventional planting after cotton harvest. So, it is concluded that farmers may be recommended to adopt this method of wheat intercropping as a relay crop in the cotton standing crop.

**Acknowledgement:** Authors are thankful to Dr. Abdul Majid, country manager ICARDA, Islamabad, Pakistan and Prof. Dr. Nazim Hussain Chairman, Department of Agronomy, Faculty of Agricultural Sciences & Technology, Bahauddin Zakariya University, Multan, Pakistan for providing the guidelines and critical review for this research under USIAD funded W-PEP project.

### References

- Ahmad, M., M. Jamil, Z. Ahmad, M.A. Kharal, A. Niaz, M. Iqbal, M.F.Z. Akhtar and M. Latif. 2016. Improving the productivity of Bt cotton (*Gossypium hirsutum* L.) through integrated plant nutrient management. *Sci. Lett.* 4(1):44-50.
- Akkaya, A. and S. Akten. 1989. Effect of different sowing dates on the yield and some yield components of winter wheat under dry land conditions at Frzurum, Tarlabitkileri, Boluu, Ataturk Universities, Fruzurm, Turkey.
- Andrew, Y., M. Hulluka and S. Ahmad. 1990. Effect of sowing dates on severity of leaf and stem rust and on yield of wheat at Debre Zeit, Sixth Regional Wheat workshop for Eastern, Central and Southern Africa, 4:59-62. CIMMYT, Mexico.
- Aslam, M., A.H. Sanghi, S. Javed and L. Khalid. 2013. Effect of sowing time on wheat yield sown in standing cotton. *J. Agric. Res.* 51(2): 133-137.
- Bange, M.P. and S.P. Milroy. 2001. Timing of crop maturity in cotton: Impact of dry matter production and partitioning. *Field Crops Res.* 68(2): 143-155.
- Butter G.S., H.S. Sidhu, V. Singh, M.L. Jat, R. Gupta, Y. Singh and B. Singh. 2013. Relay planting of

- wheat in cotton: An innovative technology for enhancing productivity and profitability of wheat in cotton-wheat production systems in South Asia. *Expl. Agric.* 49(1): 19-30.
- Conijn, J.G., P.S. Bindraban, J.J. Schröder and R.E.E. Jongschaap. 2018. Can our global food system meet food demand within planetary boundaries? *Agric. Ecosyst. Environ.* 251: 244-256.
- Du, X., B. Chen, T. Shen, Y. Zhang and Z. Zhou. 2015. Effect of cropping system on radiation use efficiency in double-cropped wheat-cotton. *Field Crops Res.* 170: 21-31.
- Feng, L., G. Wang, Y. Han, Y. Li, Y. Zhu, Z. Zhou, and W. Cao. 2017. Effects of planting pattern on growth and yield and economic benefits of cotton in a wheat-cotton double cropping system versus monoculture cotton. *Field Crops Res.* 213: 100-108.
- Feng, L., G. Wang, Y. Han, Y. Li, Y. Zhu, Z. Zhou, W. Cao. 2017. Effects of planting pattern on growth and yield and economic benefits of cotton in a wheat-cotton double cropping system versus monoculture cotton. *Field Crops Res.* 213: 100-108.
- GOP, 2004. Pakistan Economic Survey 2004-05. Government of Pakistan, Finance Division, Economic Adviser's Wing, Islamabad.
- GOP, 2012. Pakistan Economic Survey 2012-13. Government of Pakistan, Finance Division, Economic Adviser's Wing, Islamabad.
- Green C.F., G.A. Paulson and J.D. Ivins. 1985. Time of sowing and the development of winter wheat. *J. Agric. Sci.* 105(1):217-221.
- Huang, C., Q. Liu, F. Gou, X. Li, C. Zhang, W. van der Werf and F. Zhang. 2017. Plant growth patterns in a tripartite strip relay intercrop are shaped by asymmetric aboveground competition. *Field Crops Res.* 201: 41-51.
- Jan, A., I. Hammed and T. Muhammad. 2000. Seed rates and sowing dates effect on the performance of wheat variety Bakhatawar-92, *Pak. J. Biol. Sci.* 3(9): 1409-1411.
- Khan, M.B. and A. Khaliq. 2005. Production of winter cereals as relay crops surface seeding in cotton based cropping system. *J. Res. Sci.* 16(2): 79-86.
- Kirby, E.J.M. and R.P. Ellis. 1980. A comparison of spring barley grown in England and in Scotland. 1. Shoot apex development. *J. Sci.*, 95 (01): 101-110.
- Kirby, E.J.M. 1969. The effect of sowing date and plant density on barley. *Int. J. Ann. App. Bio.* 63(3): 1744-7348.
- Long, S.P., A. Marshall-Colon and X.-G. Zhu. 2015. Meeting the Global Food Demand of the Future by Engineering Crop Photosynthesis and Yield Potential. *Cell.* 161(1): 56-66.
- Mao, L., L. Zhang, X. Zhao, S. Liu, W. van der Werf, S. Zhang, H. Spiertz and Z. Li. 2014. Crop growth, light utilization and yield of relay intercropped cotton as affected by plant density and a plant growth regulator. *Field Crops Res.* 155: 67-76.
- Nawaz, H., N. Hussain, A. Yasmeen, S.A.H. Bukhari and M.B. Hussain 2017. Seed priming: a potential stratagem for ameliorating soil water deficit in wheat. *Pak. J. Agri. Sci.* 54: 241-254.
- Nayyar, M.M., M. Asghar and M.J. Tahir. 1992. Effect of sowing dates and seeding rate on wheat grain yield under irrigated conditions. *J. Agric. Res.* 30(3): 329-333.
- Noworolnik, K. and A. Pecio. 1990. Effect of N fertilizer application and sowing date and rate on the magnitude and structure of grain yield of winter barley cultivars”, *Biuletyn- Instytutu Hodowli-I Aklimatyzacji-Roslin.*, 175(11): 55-62.
- Ong, G.K. and N.R. Baker. 1985. Control of Leaf Growth, Temperature and Leaf Growth, Cambridge University Press. 175-200.
- Piech, M. and S. Stankowski. 1989. Effect of sowing dates and rate on yield and grain quality of winter wheat varieties. *Biuletyn-instytutu-Hodowli-i-Aklimatyzacji-Roslin.* 169(13): 137-147.
- Rehman, A., L. Jingdong, A.A. Chandio, I. Hussain, S.A. Wagan and Q.U.A. Memon. 2018. Economic perspectives of cotton crop in Pakistan: A time series analysis (1970-2015) (Part 1). *J. Saudi Soc. Agric. Sci.* <https://doi.org/10.1016/j.jssas.2016.12.005>
- Rehman, A., L. Jingdong, B. Shahzad, A.A. Chandio, I. Hussain, G. Nabi and M.S. Iqbal. 2015. Economic perspectives of major field crops of Pakistan: An empirical study. *Pacific Sci. Rev. B: Humanities Social Sci.* 1(3): 145-158.
- Rehmani, M.I.A., M.F. Fareed, A.M. Alvi, M. Ibrahim, N. Hussain, S. Hussain, J. Iqbal, M.A. Bashir and H. Nawaz. 2016. Delayed wheat (*Triticum aestivum* L.) cultivation and role of diverse seeding rates and row spacings under semiarid agro-climatic situations. *Pure Appl. Biol.* 5(1): 72-84.
- Sajjad A., S.A. Anjum, R. Ahmad and E.A. Waraich 2018. Relay cropping of wheat (*Triticum aestivum* L.) in cotton (*Gossypium hirsutum* L.) improves the profitability of cotton-wheat cropping system. *J. Environ. Sci. Pollut. Res.*, 25(1): 782-789

- Shah, M.A., M. Farooq, M. Hussain. 2016. Productivity and profitability of cotton–wheat system as influenced by relay intercropping of insect resistant transgenic cotton in bed planted wheat. *Eur. J. Agron.* 75: 33-41.
- Singh, M., H.S. Sidhu, J.S. Mahal, G.S. Manes, M.L. Jat, A.K. Mahal, P. Singh and Y. Singh. 2017. Relay sowing of wheat in the cotton–wheat cropping system in North-West India: Technical and economic aspects. *Exp. Agric.* 53(4): 539-552.
- Stapper, M. and R.A. Fischer. 1990. Genotype, sowing date and plant spacing influence on high yielding irrigated wheat in Southern New South Wales. II. Growth, yield and nitrogen use. *Australian J. Agric. Res.*, 41(6): 1021-1041.
- Tahir, M., A. Ali, M.A. Nadeem, A. Hussain and F. Khalid. 2009. Effect of different sowing dates on growth and yield of wheat (*Triticum aestivum* L.) varieties in district Jhang, Pakistan. *Pak. J. Life Soc. Sci.* 7 (1):66-69.
- Tanveer, M., S.A. Anjum, S. Hussain, A. Cerdà and U. Ashraf. 2017. Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production. *Environ. Sci. Pollut. Res.* 24(8): 6973-6988.
- Ullah, A., S.R. Perret, S.H. Gheewala and P. Soni. 2016. Eco-efficiency of cotton-cropping systems in Pakistan: an integrated approach of life cycle assessment and data envelopment analysis. *J. Clean. Prod.* 134: 623-632.
- Vrignon-Brenas, S., F. Celette, A. Piquet-Pissaloux, C. David. 2016a. Biotic and abiotic factors impacting establishment and growth of relay intercropped forage legumes. *Eur. J. Agron.* 81: 169-177.
- Vrignon-Brenas, S., F. Celette, A. Piquet-Pissaloux, M.-H. Jeuffroy and C. David. 2016b. Early assessment of ecological services provided by forage legumes in relay intercropping. *Eur. J. Agron.* 75: 89-98.
- Vrignon-Brenas, S., F. Celette, C. Amossé, C. David. 2016c. Effect of spring fertilization on ecosystem services of organic wheat and clover relay intercrops. *Eur. J. Agron.* 73: 73-82.
- World Bank, 2017, <https://data.worldbank.org/country/Pakistan>
- Yadvinder, S., S.S. Kukal, M.L. Jat and H.S. Sidhu. 2014. Chapter Four - Improving Water Productivity of Wheat-Based Cropping Systems in South Asia for Sustained Productivity. In: Sparks, D. (Ed.), *Adv. Agron.* Academic Press, p. 157-258.
- Zhang, L., W. van der Werf, L. Bastiaans, S. Zhang, B. Li and J.H.J. Spiertz. 2008. Light interception and utilization in relay intercrops of wheat and cotton. *Field Crops Res.* 107(1): 29-42.
- Zhang, L., W. van der Werf, S. Zhang, B. Li and J.H.J. Spiertz. 2007. Growth, yield and quality of wheat and cotton in relay strip intercropping systems. *Field Crops Res.* 103(3): 178-188.
- Zhou, G., X. Yin, Y. Li, H. Yang, Z. Zhao, P. Che, Q. Cao, H. Zhao, Y. Wang and L. Xu. 2014. Effects of relay cropping of corn on the productivity and quality of flue-cured tobacco. *Agron. J.* 106(5): 1651-1658.
- Zhou, G., X. Yin, Y. Li, Z. Zhao, L. Xu and J. Ding. 2015. Optimal planting timing for corn relay intercropped with flue-cured tobacco. *Crop Sci.* 55(6): 2852-2862.
- Zia-ul-Hassan, M., A.J. Wahla, M.Q. Waqar and A. Ali. 2014. Influence of sowing date on the growth and grain yield performance of wheat varieties under rainfed condition. *Sci. Tech. Dev.* 33(1): 22-25.

#### INVITATION TO SUBMIT ARTICLES:

Journal of Environmental and Agricultural Sciences (JEAS) (ISSN: 2313-8629) is an Open Access, Peer Reviewed online Journal, which publishes Research articles, Short Communications, Review articles, Methodology articles, Technical Reports in all areas of **Biology, Plant, Animal, Environmental and Agricultural** Sciences. For manuscript submission and information contact editor JEAS at [dr.rehmani.mia@hotmail.com](mailto:dr.rehmani.mia@hotmail.com).

Online Submission System <http://www.agropublishers.com>

Follow JEAS at Facebook: <https://www.facebook.com/journal.environmental.agricultural.sciences>

Join LinkedIn Group: <https://www.linkedin.com/groups/8388694>