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RESEARCH PAPER

Influence of wheat based intercropping system by irrigation scheduling under limited water conditions

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Abstract : An experiment was conducted during three consecutive years of *Rabi* (2011-12 to 2013-14) at Agricultural Research Station-Ummedganj, Agriculture University, Kota (Rajasthan) on wheat based intercropping system. The experiment consisted of ten treatment combinations *viz.,* two irrigation regimes (IW/CPE ratio 0.4 and 0.6) and five intercropping system (wheat + gram (6:4), wheat + mustard (6:4), wheat + fenugreek (6:4), wheat + field pea (6:4) and sole wheat) were under taken in split plot design with four replications.It is evident from pooled data the maximum wheat equivalent yield (53.68 q/ha) was observed with irrigation regime at IW/CPE ratio 0.6 over application of IW/CPE ratio 0.4 (45.04 q/ha). Among intercropping, wheat + gram (6:4) intercropping system gave significantly higher wheat equivalent yield (58.50 q/ha) overwheat + mustard (6:4)(50.91 q/ha), wheat + fenugreek (6:4)(46.28 q/ha) and wheat + field pea (6:4)(46.08 q/ha) intercropping system as well as sole wheat (45.04 q/ha), respectively. Significantly higher water use efficiency (23.49kg/ha-cm) was recorded under wheat + gram (6:4) intercropping system over wheat + mustard (6:4), wheat + fenugreek (6:4) and wheat + field pea (6:4) intercropping system as well as sole wheat.The maximum net return (Rs.55810/- ha^{-1}) and B:C ratio (3.6) was observed with irrigation regime at IW/CPE ratio 0.6 as compared to IW/CPE ratio 0.4. Among intercropping, wheat + gram (6:4) intercropping system gave significantly higher net return (Rs.62426/- ha^{-1}) and B:C ratio (4.0) over wheat + mustard (6:4), wheat + fenugreek (6:4) and wheat + field pea (6:4) intercropping system as well as sole wheat.

Key Words : Inter cropping, Irrigation regimes, Water use efficiency, Wheat equivalent yield

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's most important staple crops, with over 2.5 billion people eating it in 89 countries. Wheat is an important cereal crop of Indo-Gangetic plains of India in general and it is generally grown as an irrigated crop. Wheat is grown on a total of 31.45 million hectares in India, with a production of 107.60 million tonnes and productivity of 3420 kg/ha (USDA, 2020). In general, because the need for land for other sectors will continue to rise, there is

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little opportunity to bring additional areas entirely under pulses, oilseeds, or even wheat. As a result, the only option is to increase crop productivity. Intercropped oilseeds and pulses may be a more efficient use of resources than a single crop for enhancing productivity and profitability. Pulses and oil seed crops are most important in India, whereas wheat is the most demanded food grain crop. These crops are primarily grown in irrigated conditions during *Rabi* season in a wide range of soils and climates (Pimpale *et al*., 2015). Thus, their intercropping can prove feasible and profitable.

Water is one of the vital inputs in farming and its availability is tending to become ever more scare and costlier due to increased industrialization, intensive agriculture and climate change. Water supply will be the major natural resource constraint, restraining economic development and food grain production in India. Hence, conservation of water and its efficient use has alleged much significance at recent times. The foremost prospect for increasing efficiency of water use at farm level lies in identifying the crop water requirement throughout its growth. Under irrigated situation, plants extract water from field capacity to permanent wilting point. This phenomenon can be regulated by proper irrigation scheduling in such a way that it does not compensate with the yield of the crop. Irrigation scheduling differs from crop to crop whose identification helps in saving water while maintaining the soil moisture level. Effective utilization of available water resources is crucial for countries like India which share about 17% of the global population with only 2.4% of land. Agriculture is largest user of water, consuming more than 80% of the country's exploitable water resources. It isestimated that the allocation is to be reduced to 71% in the next two decades. Development of appropriate water management technologies to maximize the crop productivity per drop of water is the need of the hour (Kumar *et al*., 2017). Increased water uses efficiency of crops can be possible through appropriate irrigation scheduling by providing only the water that match the crop evapotranspiration and irrigating at critical growth stages (Deng *et al*., 2006). Regulated irrigation under intercropping system are very promising when the optimum irrigation scheduling is identified for the crop at particular agro-climatic zone. Irrigation schedules can be classified as full and deficit irrigation, on basis of plant, soil and climatic conditions (Fabeiro *et al*., 2002). Proper irrigation scheduling provides means of reducing water wastage through evaporation with increased yields (Molden *et al*., 2010). Intercropping system is generally more productive than sole crop (Ijoyah *et al*., 2013) and also, could be a way of saving irrigation water (Walker *et al*., 2005).

Crop diversification could be adopted as a strategy in employment generation throughout the year and also maximizing the profit through reaping the gains by equating the substitution and price ratios for competitive products (Deshpande *et al*., 2007). Intercropping provides scope for improving the productivity and monetary return per unit area per unit time (Annadurai and Uthayakumar, 2010). The success of any intercropping system relies on the appropriate selection of companion crop where, competition between them for radiation, CO_2 nutrients, moisture, spaces etc., is minimized (Willey and Reddy, 1981). Usually partner crops belonging to the same family or types or growth durations are competitive for natural resources whereas the crops of different categories, such as cereals and legumes, are generally complementary in nature thus, mutually benefited (Keating and Carberry, 1993). Land has become a limiting factor due to rapid industrialization and urbanization creating an inequality amid demand and supply of edible oil and pulses due to lower production of crops. Further, the shortage of pulses and edible oil along with cereals has also aggravated the problem of malnutrition. This can be achieved by increasing the productivity from the existing area by adopting appropriate agronomic practices, of which intercropping system can be depended as one of the best ways to increase productivity from unit available land (Chaudhari *et al*., 2017). The intercropping system is an essential possibility which not only aims at increasing productivity at a particular time, but also insurances against total crop failure under aberrant weather conditions. The yield advantages in intercropping systems are coupled with complete utilization of environmental resources over time and space (Natarajan and Willey, 1986). The data available on the wheat based intercropping system and its performance under different irrigated condition is inadequate due to insufficient research work. Therefore, the present research was undertaken to study the effect of different irrigation regimes on yield and monetary returns of wheat and its water use efficiency under intercropping system.

MATERIAL AND METHODS

An experiment was conducted on wheat based intercropping systemduring three consecutive years of *Rabi* (2011-12 to 2013-14) at Agricultural Research Station, Ummedganj, Kota, which is situated at South-Eastern part of Rajasthan. In Rajasthan, this region falls under Agro-climatic zone Vth B humid south eastern plains of Rajasthan. It is located between 25^{0}13′ N latitude and 75^{0}25′ E longitudes at an altitude of 258 m above mean sea level. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 20.8 °C to 38.0 °C and 04.0 °C to 23.0 °C during *Rabi* season. The annual rainfall ranges from 550 mm to 1400 mm, most of which (80-85 %) is received during July to September from south-west monsoon, whereas winter showers occur occasionally. The soil of experimental site was clay loam in texture, slightly alkaline in reaction. Soil testing results revealed that the experimental soil was medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha^{-1}) while high in potassium (388 kg ha^{-1}) with pH (7.6) and EC (0.52 dS m^{-1}). The entire quantity of P and K fertilizers was applied in basal as a single dose, whereas N fertilizer was used in three splits. Under intercropping system row ratio was maintain as per treatment irrigation was also applied as per irrigation regimes of the experiment.

The experiment consisted of ten treatment combinations *viz.,* two irrigation regimes (IW/CPE ratio 0.4 and 0.6) and five intercropping system (wheat + gram (6:4), wheat + mustard (6:4), wheat + fenugreek (6:4), wheat + field pea (6:4) and sole wheat) were under taken in split plot design with four replications.The varieties Wheat-HI 8498, Mustard-Pusa Bold, Chickpea-GNG-469, Fenugreek- RMT-1 and Field pea- Arkil were sown by bulk pair operated seed drill. Sowing was done in the row 22.5 cm for sole wheat with intercrops under replacement series at a depth of 3-5 cm. Data on wheat equivalent yield, water use efficiency, net returns and B: C ratio were recorded as per standard procedures. The data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

Crop equivalent yield (CEY) was calculated by following formula:

$$\text{CEY} = \frac{\text{Intercrop yield (kg ha}^{-1}\text{) x Price of intercrop yield (Rs. kg}^{-1}\text{)}}{\text{Price of main crop (Rs. kg}^{-1}\text{)}}$$

Irrigation water use efficiency was estimated as the ratio of seed yield (kg/ha) and irrigation water applied (mm) based on below formula :

$$\text{WUE} = \frac{\text{Seed yield (kg/ha)}}{\text{Irrigation water applied (mm)}}$$

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads :

Effect of irrigation regimes on wheat equivalent yield :

A perusal of data presented in Table 1 showed that the application of increasing irrigation regimes significantly increases wheat equivalent of wheat based intercropping system. It is evident from pooled data the maximum wheat equivalent yield (53.68 q/ha) was observed with irrigation regime at IW/CPE ratio 0.6 over application of IW/CPE ratio 0.4 (45.04 q/ha). The irrigations generally impacton wheat yield and water use efficiency (Galavi and Moghaddam, 2012). The timing of irrigation

Table 1 : Effect of irrigation regimes and wheat based intercropping system on wheat equivalent yield and water use efficiency

Treatments	Seed yield (t ha^{-1})				WUE (kg ha-mm^{-1})			
	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled
Irrigation regimes								
IW/CPE 0.4	43.95	44.07	47.11	45.04	19.97	20.03	21.41	20.47
IW/CPE 0.6	52.43	55.90	52.72	53.68	18.72	19.96	18.75	19.15
S.E.±	0.51	0.38	1.17	0.61	0.34	0.21	0.45	0.30
C.D. (P=0.05)	1.76	1.32	5.26	2.74	NS	NS	2.06	NS
Intercropping system								
Wheat + Gram (6:4)	57.02	60.28	58.21	58.50	22.84	24.12	23.48	23.49
Wheat + Mustard (6:4)	52.68	48.23	51.82	50.91	21.23	19.32	20.73	20.43
Wheat + Fenugreek (6:4)	43.14	48.48	47.24	46.28	17.38	19.35	18.93	18.56
Wheat + Field pea (6:4)	44.23	46.95	47.06	46.08	17.79	18.86	19.03	18.57
Sole wheat	43.88	46.00	45.24	45.04	17.48	18.32	18.22	18.01
S.E.±	1.11	0.71	1.570	1.01	0.68	0.43	0.64	0.53
C.D. (P=0.05)	3.19	2.05	4.581	2.86	NS	1.27	1.88	1.49

NS= Non-significant

is also essential for water management. Irrigation failure at some critical growth stages drastically reduces grain yield (Kumar *et al*., 2014) due to lower test weight. Rosette, pre-flowering and pod development stages are crucial mustard growth stages that require irrigation. Two irrigations applied to mustard at the pre-flowering + grain filling stages considerably improve growth and yield-related characteristics (Singh *et al*., 2018). The most crucial choice for boosting water production in a stressful environment will be appropriate water management with irrigation scheduling based on a critical growth stage approach (Rizkand Sherif, 2014).

Effect of irrigation regimes on water use efficiency:

A reference to pooled data presented in Table 1 showed that the water use efficiency of wheat based intercropping system did not significantly influence under different irrigation regimes during experimentation. The water use efficiency under intercropping system is numerically increase with irrigation regime at IW/CPE ratio 0.4 over application of IW/CPE ratio 0.6, but did not significantly influence under various regimes. Development of appropriate water management technologies to maximize the crop productivity per drop of water is the need of the hour (Kumar *et al*., 2017). Increased water uses efficiency of crops can be possible through appropriate irrigation scheduling by providing only the water that match the crop evapotranspiration and irrigating at critical growth stages (Deng *et al*., 2006).

Effect of irrigation regimes on economics :

It is evident from pooled data presented in Table 2 showed that the monetary returns of wheat based intercropping system significantly increase under application of various irrigation regimes. The maximum net return (Rs.55810/- ha^{-1}) and B:C ratio (3.60) was recorded with irrigation regime at IW/CPE ratio 0.6 as compared to IW/CPE ratio 0.4 (Rs.44278/- ha^{-1}) and B:C ratio (2.81). This might be due to intercropping system obtaining a higher yield and its market price coupled with better utilization of the agronomic resources more effectively and efficiently towards increased production and monetary return of the system. Similar results were reported by Ebrahimi *et al*. (2017) and Biswas *et al*. (2019).

Effect of intercropping system on wheat equivalent yield :

A perusal of data presented in Table 1 showed that the wheat equivalent yield was significantly influence under wheat based intercropping system. Among intercropping, wheat + gram (6:4) intercropping system gave significantly higher wheat equivalent yield (58.50 q/ha) over wheat + mustardrow ratio 6:4(50.91 q/ha), wheat + fenugreek row ratio 6:4(46.28q/ha) and wheat + field pea row ratio 6:4 (46.08 q/ha) intercropping system as well as sole wheat (45.04 q/ha), respectively in the pooled analysis. This may be due to better vegetative growth coupled with higher yield attributes resulted in higher grain yield as compare to sole crop. This was in harmony with the findings of Singh *et al*. (2018), Pal *et al*. (2020) and Maurya *et al*. (2022). The yield attributed gave higher yield of both component crops because of better compatibility for resource utilization.

Table 2 : Effect of irrigation regimes and wheat based intercropping system on net returns and B: C ratio

Treatment	Net return (Rs. ha^{-1})				B: C ratio			
	2011-12	2012-13	2013-14	Pooled	2011-12	2012-13	2013-14	Pooled
Irrigation regimes								
IW/CPE 0.4	41633	44003	47197	44278	2.70	2.85	2.88	2.81
IW/CPE 0.6	52507	59808	55115	55810	3.37	3.84	3.59	3.60
S.E.±	935	728	1255	875	0.06	0.05	0.12	0.06
C.D. (P=0.05)	4208	3274	5647	3938	0.48	0.42	0.53	0.43
Intercropping system								
Wheat + Gram (6:4)	58858	66105	62316	62426	3.86	4.33	3.83	4.00
Wheat + Mustard (6:4)	52738	49358	54453	52183	3.35	3.13	3.29	3.26
Wheat + Fenugreek (6:4)	40756	50117	47443	46105	2.66	3.27	2.90	2.94
Wheat + Field pea (6:4)	42808	48692	47836	46445	2.91	3.31	3.05	3.09
Sole wheat	40192	45254	43731	43059	2.38	2.67	2.52	2.52
S.E.±	2171	1447	2064	1705	0.14	0.09	0.31	0.16
C.D. (P=0.05)	6335	4223	6025	4804	0.41	0.47	0.54	0.45

These results confirm the findings of Singh *et al*. (1992). Wheat equivalent yield increased with each wider row ratio in wheat, linseed or mustard intercropping but reduced in wheat +chickpea intercropping numerically. These findings are in collaboration with Mallik *et al*. (1993).

Effect of intercropping system on water use efficiency :

A reference to pooled data presented in Table 1 showed that the water use efficiency of wheat based intercropping system was significantly increase under various cropping systems. Significantly higher water use efficiency (23.49kg/ha-cm) was recorded under wheat + gram (6:4) intercropping system overwheat + mustardrow ratio 6:4(20.43kg/ha-cm), wheat + fenugreek row ratio 6:4(18.56kg/ha-cm) and wheat + field pea row ratio 6:4 (18.57kg/ha-cm) intercropping system as well as sole wheat (18.01kg/ha-cm). Intercropping systems are generally recommended for rainfed crops to get stable yields. The total water used in intercropping system is almost the same as for sole crops, but yields are increased, thus water use efficiency is higher than sole crops (Singh *et al*., 2013d). It is found that good agronomic practices not only improve better utilization of water but also proved an eco-friendly tool for sustainable management of plant diseases under changing climate scenario (Singh *et al*., 2012c and Singh *et al*., 2013b).

Effect of intercropping system on economics :

A perusal of data presented in Table 2 showed that the monetary return was significantly increase under wheat based intercropping system. Among intercropping, wheat+gram (6:4) intercropping system gave significantly higher net return (Rs.62426/- ha^{-1}) and B:C ratio (4.0) over wheat + mustard row ratio 6:4 (Rs.52183/- ha^{-1}) and B:C ratio (3.26), wheat + fenugreek row ratio 6:4 (Rs.46105/- ha^{-1}) and B:C ratio (2.94) and wheat + field pea row ratio 6:4 (Rs.46445/- ha^{-1}) and B:C ratio (3.09) intercropping system as well as sole wheat (Rs.43059/- ha^{-1}) and B:C ratio (2.52). Intercropping of oil seeds and pulses along with cereals may be a more efficient use of resources than a single crop for enhancing productivity and profitability. Intercrops, may be highly effective at suppressing weeds, resulting in better yields and profits (Singh *et al*., 2010). These results may very well be supported by the findings of Singh *et al*. (1992). The intercropping treatment of wheat +chickpea being at par with wheat +linseed in 6:2 row ratio than sole wheat, attained higher values of B:C ratios. These are attributed to higher net income in wheat +chickpea intercropping's and to combined effects of lower cost and higher income in case of wheat +linseed in 6:2 row ratio and sole wheat treatments. Findings of Singh *et al*. (1992) and (Srivastav and Bohra, 2006) are in agreement to the results of present investigation in this respect.

It is concluded that the application of irrigation schedule IW/CPE ratio 0.6 gave significantly higher wheat equivalent yield, net return and B: C ratio and also increase water use efficiency. Under wheat + gram (6:4) intercropping system also recorded higher wheat equivalent yield, water use efficiency, net return and B: C ratio. Hence, this irrigation regime and intercropping system is proved as productive and beneficial.

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