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EFFECT OF CROPPING SYSTEMS, TILLAGE PRACTICES AND FERTILIZER TREATMENTS ON WHEAT STAND ESTABLISHMENT UNDER RAINFED CONDITIONS

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ABSTRACT: Wheat stand establishment was studied in a randomized complete block design (cropping systems x tillage practices x fertilizer treatments) under rainfed condition, during 2000-01 and 2000-02. On the basis of wheat emergence (m^{-2}) and emergence rate index, wheat stand establishment was significantly ($P<0.05$) higher in the fallow-wheat cropping system compared to maize-wheat, mungbean-wheat, and cowpea-wheat system. Tillage practices (shallow and deep) and fertilizer treatments {recommended dose of fertilizer (F); fertilizer + manure (F+FYM); manure only (FYM) and control (C)} did not show significant effect on both emergence and emergence rate index. Overall, significantly ($P<0.05$) higher residual soil moisture content was available in fallow-wheat system which resulted in better wheat emergence. This ultimately resulted in vigorous crop stand establishment. The biomass harvest observed at 2-3 leaf stage in the fallow-wheat system was higher than other systems under study.

Key Words: Triticum aestivum; Cropping Systems; Tillage; Fertility; Emergence; Harvest Index; Rainfed Conditions; Pakistan.

INTRODUCTION

Wheat (*Triticum aestivum L.*) is a staple food crop of many countries including Pakistan. The wheat in Pakistan is grown under diversified environments, however, it is mainly grown under irrigated and rainfed conditions. The rainfed wheat contributes almost 30% in the total wheat produced in the country. The productivity of rainfed wheat mainly depends on the amount of soil moisture for which rainfall is the major source. In rainfed areas wheat is usually planted on residual moisture of summer (monsoon) rains or some times early winter rains (October – November) that provides watter conditions (soil moisture at optimum level) for wheat planting. The rains in these areas are scanty, erratic and torrential in nature. Thus the wheat crop stand establishment (WSE) largely depends on the residual soil moisture and occurrence of rainfall at the time of wheat sowing. During October when the rains does not occur the moisture in the upper soil surface depletes due to evaporation that resulted in less available soil moisture for wheat germination. Wheat stand establishment is critical where soil surface is wetted infrequently/irregularly and the rate of evaporation is high (Hillel, 1982). Farmers usually conserve soil moisture using different ways. In rainfed areas success of WSE mainly depends on conserved summer (*kharif*) moisture. About 80% of the farmers in rainfed areas growing wheat are practicing fallow-wheat cropping system (Razzaq et al., 2002). *Kharif* fallowing is a common practice to conserve moisture, so the fallow system is sustained through immense number (10-14) of tillage operations (Zahid et al., 1991). Ishaq et al. (2003) reported that farmers of rainfed area tilled the land excessively in fallow-wheat cropping system than wheat-summer crop just to conserve rain water and control weeds. It is envisaged that if some cover crop like maize fodder or legume are grown in *kharif* instead of fallow, the more moisture in the Supper profile may be made available due to mulching effect of dropped leaves and crop shading (Papendick and Cambell, 1974). Mucha (2001) reported

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that typical rotation along with managing the soil moisture and plant nutrients gave highest returns. However, a disadvantage of continuous cropping in semi-arid region is the increased chances of crop failure due to in abdicate soil water to support economic crop yields (Timsina and Connor, 2001).

In addition to adopt crop management techniques (as discussed in the previous paragraphs) the use of different tillage practices are common for this purpose. Some of the most common tillage practices universally adopted are deep tillage, zero-tillage and reduced tillage. In rainfed agriculture of Pakistan moldboard and chisel plough are used for deep tillage to break a hard pan or loosen the compact sub-surface soil, allowing improved infiltration of rainwater and to check erosion. Moldboard is more popular than chisel plough because it is widely available and its inversion process controls weeds. The tillage practices affect on the osmotic pressures in the soil solution, the seed-soil contact, soil strength and volume of gaseous phase which play an important role in the germination of seeds as well as in the establishment of seedlings (Mitchell, 1970). Warkentin (2000) stated that main objective of tillage is to change soil physical conditions and control weeds. Ahmad et al. (1990) concluded that deep ploughing before the start of monsoon conserves moisture for wheat planting. The number of seedlings emerged in the deep ploughing was higher as compared to shallow cultivation. Drinkwater et al. (2000) reported that deep tillage resulted in conservation of soil water in lands where process of rain water infiltration, runoff and evaporation are involved. Some scientists (David et al., 2002; Warkentin, 2000) are of the opinion that tillage practices may help in improving the physical conditions of the soil, incorporation of organic residues into the soil, enhancing water infiltration, reducing runoff and improving nutrient availability. They concluded that yield was significantly increased by moldboard plough in comparison to other tillage treatments. Most researchers (Lal, 1997; Diaz-Zorita, 2000) agree that crop response to deep tillage is function of several interacting factors including crop species, soil and climatic conditions and weather fluctuations. David et al. (2002) stated that advantages of deep tillage for crop yield depend upon rainfall pattern, i.e., amount and its distribution and plant type (i.e. rooting pattern and growth duration). Antapa and Mariki (2000) indicated that volumetric water contents were consistently greater in soils managed under deep tillage than those under conventional tillage systems.

The soils of rainfed areas are low in organic matter and deficient in nitrogen and phosphorous (Rashid et al., 1994). The soil organic matter and fertility status also affects the ionic concentration of soil solution, thus the effect on stand establishment because the germination percentage obtained was not strictly a function of the water uptake by the seeds. However, the transient exposure to high osmotic pressures (low, i.e. negative osmotic potentials) can promote subsequent germination in the soil; shorten the time required for germination and increase germination percentage. Resultantly more even crop stand was obtained (Ali, 1998). Fertilizer and manure affect on the ionic concentration of soil solution. The germination percentage obtained is not strictly a function of the water uptake by the seeds. However, the transient exposure to high osmotic pressures (low, i.e. negative osmotic potentials) can promote subsequent germination in the soil, shorten the time required for germination and increase germination percentage. Hillel (1982) reported that many soils and particularly arid-zone soils that are low in organic matter content and often have low vegetative cover tend to form a dense crust under the beating and shaking action of raindrops, and soil crusting has long been known to restrict germination and seedling emergence, either by forming a mechanical obstruction or by limiting aeration or combination of these effects. Sharma and Singh (1996) reported that the application of FYM in conjunction with mineral fertilizer resulted in higher grain production of maize than applying fertilizer and FYM alone. Similarly, Mahajan (1996) concluded that FYM was useful in increasing the yield of maize and wheat by 27% and 20%, respectively. This experiment was designed to evaluate wheat stand estalishment from emergence to 2-3 leaf stage among different cropping systems, tillage practices and fertilizer treatments.

MATERIALS AND METHODS

The study was conducted under rainfed conditions in Pothwar plateau for two years (2000-02), at National Agricultural Research Centre (NARC), Islamabad. The experimental site is located in sub-humid, subtropical region, 510 m above sea level, at 73.08 ^{0}E and 33.42 ^{0}N. The experiment was designed to study the effect of four wheat (*Triticum aestivum* L.) based cropping systems, i.e., fallow-wheat-fallow-wheat, maize fodder-wheat-maize fodder-wheat, cowpea-wheat-cowpea-wheat and mungbean-wheat-mungbean-wheat, two tillage systems: shallow (cultivator) and deep (moldboard) with four fertilizer treatments i.e. control (C), recommended dose of fertilizer (F), fertilizer plus farm yard manure (F+FYM) and farm yard manure (FYM) alone on stand establishment of wheat under rainfed conditions. This cropping system trial was completed in two cycles and every cycle had two phases i.e. *rabi* and *kharif*. The studies were initiated for *kharif* phase during *kharif* 2000 with sowing of mungbean, cowpea and maize fodder in the respective plots. Wheat was planted during "*rabi*" 2000-01 in all plots as second phase of the study. This completed one cycle of the cropping system. In second cycle of the trial same order of pre-assigned *kharif* crops were sown in the respective (as in first cycle) plots during *kharif* 2001, and again wheat was planted in all plots during *rabi* 2001-02.

The experiment was laid out in randomized complete block design (RCBD) and treatments were arranged in split plot fashion with three replications. Cropping systems were placed in the main plots, tillage practices in the sub-plots and fertilizer treatments in the sub-sub plots. For land preparation one deep tillage treatments with moldboard was given to the soil after harvest of summer crop before on set of monsoon.

Final land preparation in all plots was done with cultivator and then the surface was planked to ensure a firm seed bed. Recommended dose of fertilizers for each crop and farmyard manure @ 5 t ha^{-1} were broadcasted in the respective plot and incorporated with cultivars (Table 1). Wheat cultivar "Chakwal 86" was planted on November 25, 2000 and November 21, 2001 with Nardi drill. Seed rate used was 100 kg ha^{-1} while row to row spacing was kept at 25 cm.

Table 1. Cultural practices for *kharif* and *rabi* crops

Parameter	Mung bean	Cow pea	Maize fodder	Wheat
Variety	MN-209	Local	Gauher	Chakwal-97
Seed rate kg ha^{-1}	25	25	50	100
Fertilizer (kg ha^{-1})				
N	20	20	100	90
P	50	50	50	90
FYM (t ha^{-1})	5	5	5	5
Row spacing (cm)	25	25	25	25

Seedlings were counted at interval of 24h from lm^2 marked area. Counting started with the beginning of emergence and was continued until emergence counts were constant in each plot. Emergence rate index (ERI) was calculated using a modified method described by Maguire (1962).

$$\text{ERI} = \left(\frac{\text{Number of normal seedlings}}{\text{Days to first count}} + \ldots\ldots\ldots\ldots + \frac{\text{Number of normal seedlings}}{\text{Days to final count}}\right)$$

Moisture contents before sowing at three different depth (0-15cm, 15-30cm and 30-60cm) were determined by using the gravimetric method (Page et al., 1982). After stand establishment one biomass harvest at 2-3 leaf stage was also taken. Analysis of variance was accomplished by using MSTAT-C computer package.

RESULTS AND DISCUSSION

Productivity of the rainfed areas in Pakistan is largely dependent on rainfall which is unpredictable. Huge variations above and below normal rainfall have been observed from long-term as well as short-term rainfall pattern. Rainfall pattern recorded during the study period was above normal during *kharif* and far below normal in *rabi* (Table 2). During *kharif* 2000 rainfall of 1144 mm and in *kharif* 2001 rainfall of 965 mm was recorded. The rainfall pattern during 2000 *kharif* was torrential whereas light showers were evenly distributed during 2001 season. Hence, the rainfall pattern during 2001 was environment friendly and created more conducive conditions for seed emergence and crop growth so these were better in *kharif* 2001. The rainfall during 2000 was heavy and torrential, which lowered the performance of mungbean especially at flowering and pod filling stages thus reduced the mungbean yield. The fodder crops (maize and cowpea) escaped from the ill effects of heavy rains; therefore, crop establishment and resultant yields during both the years were close to potential level.

The *rabi* seasons faced severe drought (*rabi* 2000-01 received only 50.1 mm rainfall, therefore, 50 mm crop saving irrigation was applied and *rabi* 2001-02 received 122 mm rainfall). The *rabi* 2000-01 was drier than *rabi* 2001-02, therefore crop yield

Table 2. Weekly rainfall data during *kharif* crops study period (May-September 2000 and 2001) and *rabi* crop study period (October-April 2000-01 and 2001-02) (mm)

Week	May 2000	June 2000	July 2000	August 2000	Sept. 2000
1st	0.0	1.2	28.4	31.5	62.0
2nd	0.7	6.5	60.9	117.5	140.0
3rd	0.0	0.0	40.0	85.0	210.0
4th	0.5	101.5	96.5	49.5	113.0
Total	1.2	109.2	225.8	283.5	**525.0**
G. Total					**1144.7**
Week	May 2001	June 2001	July 2001	August 2001	Sept. 2001
1st	25.0	42.5	53.2	22.2	2.0
2nd	0.0	30.5	170.9	70.3	25.2
3rd	14.0	29.8	286.5	48.4	2.1
4th	7.0	54.5	80.4	0.0	0.0
Total	46.0	157.3	591.0	140.9	**29.3**
G. Total					**964.5**

B.

Week 2000	October 2000	Nov 2000	December 2001	January 2001	February 2001	March 2001	April 2001
1st	0.0	0.0	0.0	0.0	0.0	0.0	1.5
2nd	0.0	0.0	12.0	0.0	0.0	6.0	4.0
3rd	0.0	0.0	0.0	0.0	0.3	0.0	4.8
4th	0.0	0.0	0.0	0.0	0.3	21.2	0.0
Total	0.0	0.0	12.0	0.0	0.6	27.2	**10.3**
G. Total							**50.1**
Week	October 2001	Nov. 2001	December 2001	January 2002	Feb. 2002	March 2002 2002	April 2002
1st	4.4	4.1	0.0	0.0	4.1	0.0	3.5
2nd	18.5	0.0	0.0	15.4	0.1	23.9	0.0
3rd	0.0	0.0	1.1	2.5	10.5	12.0	1.9
4th	0.0	0.0	0.1	0.0	9.3	5.5	5.1
Total	22.9	4.1	1.2	17.9	24.0	41.4	**10.5**
G. Total							**122.0**

and yield components were better during 2001-02. The soil of experimental area was low in organic matter, nitrogen and phosphorous; however, potassium level was adequate.

The perusal of the data (Figure 1) indicated that the wheat emergence in various cropping systems differed significantly ($P<0.05$). However, the emergence of wheat was not affected by tillage practices. Significantly higher number of seedlings emerged in fallow-wheat (272 m^{-2}) and the lowest were observed in cowpea-wheat (173 m^{-2}) cropping systems. The tillage system x cropping system interaction was significant and the highest number of wheat seedling emergence was observed in fallow-wheat with deep tillage (279 m^{-2}) and lowest seedling emergence was recorded in the interaction of cowpea-wheat x shallow tillage. These results are in line with the findings of Antapa and Mariki (2000) who reported that wheat growth and productivity depends on the rotation followed by the wheat crops among. They concluded that wheat emergence was significantly higher in a fallow cropping system than the cropped fields.

Emergence Rate Index (ERI) of Wheat

The ERI of wheat also varied significantly among various cropping systems under study. The data revealed that the emergence rate index was significantly higher in fallow-wheat compared to other cropping systems (Table 3) . Lowest ERI was observed in cowpea-wheat cropping systems. The ERI was highest in fallow-wheat

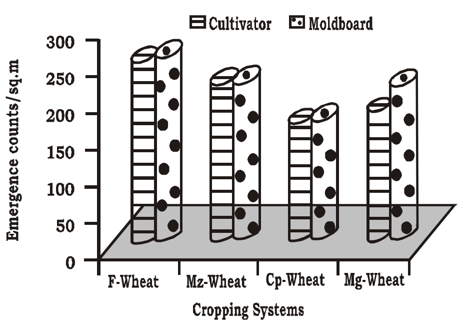

Figure 1. Emergence counts of wheat as affected by cropping systems and tillage practices

Table 3. Emergence Rate Index of wheat in different cropping systems x tillage practices

Cropping system	Tillage practices		Mean
	Shallow tillage	Deep tillage	
Fallow-Wheat	114.82 ab	131.2 a	123.2 A
Maize-Wheat	100.8 ab	70 cb	85.6 B
Cowpea-Wheat	78.4 b	71.6 b	75.2 C
Mungbean-Wheat	69.6 b	88.4 ab	78.8 B
Mean	90.8 NS	90.4 NS	

Means followed by same letter(s) do not differ significantly at P <0.05

(131) with deep tillage and lowest in maize wheat (70) with shallow tillage compared to other cropping patterns in relation to tillage systems under study.

Stand Establishment of Wheat as affected by Cropping System x Fertilizer Treatments

Emergence of Wheat

A perusal of the data indicated that the wheat emergence in various cropping systems differed significantly ($P<0.05$). However, the emergence of wheat was not affected by fertilizer treatments (Table 4) Significantly higher number of seedlings emerged in fallow-wheat (272 m^{-2}) and lowest was observed in cowpea-wheat cropping system (173 m^{-2}). The fertilizer treatments x cropping patterns interaction were significant. The highest seedling emergence was observed in the interaction maize–wheat x FYM (291m^{-2}) and lowest in cowpea-wheat with recommended fertilizer (153 m^{-2}).

Emergence Rate Index of Wheat (Cropping Systems x Fertilizer Treatments)

The ERI compared to other cropping systems in relation to fertilizer treatments under study was highest in fallow-wheat (150.4) and lowest in cowpea–wheat (48.8) both were in control. The fertilizer treat-

Table 4. Wheat emergence counts (m^3) in different cropping systems and fertilizer treatments

Cropping system	Recommended fertilizer	Control fertilizer	Manure with rec. fertilizer	Manure only	Mean
F-Wheat	241.2 a-d	298 a	278.8 abc	268.8 abc	271.6 A
Mz-Wheat	271.2 abc	202.8 a-d	199.2 a-d	290.8 ab	240.8 AB
C-Wheat	153.2 d	160.8 d	192.4 a-d	184 bcd	172.8 C
Mg-Wheat	238.8ab	182.0	191.2 a-d	240.8 a-d	213.2 BC
Mean	226 NS	210.8	215.6	246	--------

Means followed by same letter(s) do not differ significantly at P <0.05

Table 5. Effect of different cropping systems and fertilizer treatments on emergence rate index of wheat

Cropping System	Recommended fertilizer	Control fertilizer	Manure with rec. fertilizer	Manure only	Mean
F-Wheat	107.2 abc	150.4 a	2131.6 ab	102.4 abc	123.2 A
Mz-Wheat	79.6 bc	78.8 bc	71.2 bc	112.4 abc	85.6 B
C-Wheat	75.2 bc	48.8 c	93.6 abc	83.2 bc	72.2 B
Mg-Wheat	96 abc	56.4 c	70.4 bc	92.8 abc	78.8 B
Mean	89.6 B	83.6 B	91.6 AB	97.6 A	--------

Means followed by same letter(s) do not differ significantly at P <0.05

ment x cropping system interaction was non-significant (Table 5).

Wheat Biomass Accumulation at 2-3 Leaf Stage

The data on dry weight of established wheat at 2-3 leaf stage in various cropping systems in relation to tillage practices and fertilizer treatments (Table 6) indicated that mean results of the dry weight of established wheat in various cropping systems differed significantly (P>0.05). Highest amount of biomass was harvested in fallow-wheat (4gm^{-2}) and lowest in mungbean-wheat (2.6g m^{-2}).

Mean dry weight production was non-significant among shallow and deep tillage practices. Fertilizer treatments have shown significant (P<0.05) impact on biomass accumulation. Higher amount of biomass harvest was recorded in F + FYM (3.8g m^{-2}) and lowest (2.2g m^{-2}) in control.

The results of this study revealed the tillage practices (shallow, deep) have put non-significant (P>0.05) impact on both emergence and ERI. This has partially contradicted the statement of Ahmad et al.

Table 6. Dry weight (g m^{-2}) of established wheat at 2-3 leaf stage in various cropping systems in relation to tillage and fertility treatments

Cropping	Shallow tillage				Deep tillage				Mean
System	F	C	MF	M	F	C	MF	M	
Fallow-Wheat	4.6 ac	3.4 ah	5.4 a	1.0 h	4.8 abc	4.2 af	3.2 ah	5.4 a	4.0 A
Maize-Wheat	2.0 ch	1.8 eh	3.6 ah	4.0 ah	1.8 dh	2.8 ah	5.0 ab	1.0 h	2.8 B
Cowpea-Wheat	3.0 ah	1.2 fgh	3.0 ah	4.8 ad	2.8 ah	1.8 fgh	3.4 ah	2.0 ch	2.8 B
Mungbean-Wheat	3.2 ah	2.6 ah	3.0 ah	2.2 bh	3.0 ah	1.2 gh	3.2 ah	3.0 ah	2.6 B
Mean(tillage)		3.0 NS					3.0		
Mean(fertility)		3.2AB	2.2 B	2.4 A	3 AB	3.2AB	2.4 AB	3.8 A	2.8 A

Means followed by same letter(s) do not differ significantly at P <0.05
F= Fertilizer, C= Control, MF= Maize Fodder, M= Mungbean

(1990) because there was no rain at the time of planting otherwise the advantage from deep plowing would have been more pronounced. Positive correlation has been found between emergence and moisture contents for both tillage practices and relatively higher degree of association in deep tillage system with significant moisture contents at 30-45 cm (Table 7). This might be suggested that emergence counts in the context of moisture contents were affected by shallow and deep tillage systems and relatively higher emergence count in deep tillage although non-significant (P>0.05) have supported the above statement. These results are in accordance with Halvorson et al. (2001) who concluded that profile water extraction increased in the deep tillage practice. The correlation between emergence rate index and moisture contents at critical depth (0-15 cm) was negative. So, this might be concluded that for ERI, tillage practices were not the limiting factors. Equal amounts of dry matter production in both type of tillage practices (Table 6) also indicated the tillage practices have shown non-significant (P>0.05) effect on both emergence and ERI.

On the basis of emergence and ERI two distinct groups of cropping systems were studied. The first group included fallow-wheat and maize-wheat. The second group contained mungbean-wheat and cowpea-wheat. First group proved superior to second group regarding both wheat emergence and ERI.

The highest emergence count and ERI for fallow-wheat are in accordance with Ahmad et al. (1990) and Aslam (1995). This might be attributed to very little rain shower before the sowing time of wheat (Table 2). The limited rains did not restore that depleted moisture in *kharif* cropped fields for good water use efficiency. Moreover higher degree of positive correlation was found among emergence, ERI and moisture contents in fallow-wheat cropping system (Table 8). Higher biomass harvest in fallow-wheat was the other evidence in favor of healthy WSE in the fallow-wheat cropping system (Table 9).

For maize-wheat second highest emergence and ERI is in accordance with the exceptional cases of maize-wheat cropping

Table 7. Correlation among wheat emergence, ERI and soil moisture contents in different tillage systems

Tillage	Emergence			ERI		
	Soil depth (cm)					
	0-15	15-30	30-45	0-15	15-30	30-45
Shallow	0.211	0.111	0.210	-0.161	-0.058	0.109
Deep	0.302	0.242	0.333*	-0.129	0.025	0.203

** Significant at 5% level of probability.*

Table 8. Correlation among wheat emergence, ERI and soil moisture contents in different cropping systems

Cropping Systems	Emergence			ERI		
	Soil depth (cm)					
	0-15	15-30	30-45	0-15	15-30	30-45
Fallow-Wheat	0.308	0.166	0.394	0.318	-0.049	0.445 A
Maize-Wheat	0.42	0.210	0.299	-0.102	-0.070	0.243 B
Cowpea-Wheat	-0.111	-0.124	-0.452	-0.196	-0.230	-0.394 B
Mungbean-Wheat	-0.388	-0.463	-0.226	-0.330	-0.278	0.058 B

Significant at 5% level of probability.

Table 9. Correlation among wheat emergence, ERI and soil moisture contents in different fertilizer treatments

Fertilizer	Emergence			ERI		
	Soil depth (cm)					
	0-15	15-30	30-45	0-15	15-30	30-45
FYM	0.468*	-0.249	0.014	-0.349	0.070	0.170
FYM + F	-0.135	-0.327	0.090	-0.062	0.181	0.041
Control	-0.571*	0.509	0.543	0.608*	0.560*	0.573*
Mean	0.041	-0.149	0.306	-0.125	0.154	0.074

**Significant at 5% level of probability.*

system (Aslam, 1995). Reasons of this were attributed to harvesting of maize as fodder in *kharif* 1999 at the peak of its water requirement stage, hence, it depleted less soil water (due to reduced life span) than the other *kharif* crops and its trash in the field provided mulch to reduce moisture loss.

Legume based cropping system, followed fallow-wheat and maize-wheat might be attributed to negative correlation among emergence, ERI and moisture contents in legume based cropping systems (Table 8). So, it might be concluded that moisture was not the limiting factors for high emergence count and rapid ERI but some other factor were involved which have lowered both the emergence and ERI. In legume based cropping system lowest biomass harvest was an evidence of low emergence and ERI.

Fertility maintenance treatments have shown non-significant (P>0.05) effect on both emergence and ERI. These results support the conclusion drawn by Ahmad et al. (1990), that soil fertility does not have much affect on the seedling emergence because the seed stored materials are utilized during the germination and emergence process. For higher emergence count, FYM has followed fertilizer alone, F+FYM and finally the control, respectively (Table 4). So, it may be generalized that FYM has positive effects on both high emergence and ERI, while control has least effect. Ali (1998) had stated that fertilizer and manure affect on the ionic concentration of soil solution. The germination percentage obtained is not strictly a function of the water uptake by the seed. However, the transient exposure to high osmotic pressures (low i.e., negative osmotic potentials) can promote subsequent germination in the soils shorten the time required for germination and increase germination percentage. As a result more even stands were obtained.

Higher degree of significant positive correlation among wheat emergence, ERI and moisture contents in fertilizer and F+FYM were strong evidences of positive affects of these fertility maintenance treatments on both emergence and ERI in the context of moisture (Table 7). Higher amounts of biomass harvest in F+FYM and least in control has provided a valid evidence of affect of fertilizer treatments on emergence and ERI than of control.

Conclusively, results have broadened the vision for the understanding of WSE in the context of emergence and ERI under rainfed conditions. Emergence and emergence rate index were significantly (P<0.05) affected by different cropping systems and non-significantly (P>0.05) by different tillage practices and fertilizer maintenance treatments. Poor WSE in legume based cropping systems compared to fallow-wheat and maize-wheat suggested that there is need of more comprehensive study in relation to different cropping systems for successful WSE under rainfed conditions.

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