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WHEAT BIOMASS AND HARVEST INDEX INCREASES WITH INTEGRATED USE OF PHOSPHORUS, ZINC AND BENEFICIAL MICROBES UNDER SEMIARID CLIMATES

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ABSTRACT

Under semiarid climate, the higher soil pH and alkalinity reduce phosphorus (P) availability and thus crop productivity. The higher prices of P-fertilizers restrict small holders to apply the required P level to their field crops. Proper P management under semiarid climates is very essantail for increaase crop productivity of smallholders. An expriemnt was work out in 2013-15 to study the impact of P management on wheat total biomass and harvest index. The expriment was worked out at the University of Agriculture, Agronomy research farm. In experiment one, treatments were: four P levels (100, 80, 60 and 40 kg P ha^{-1}), three levels of zinc (15, 10 and 5 kg Zn ha^{-1}) and three timings of beneficial microbes (BM) timings of application (at sowing, 20 DAE and 40 DAE). It was concluded from the experiment one, that application of 80 kg P ha^{-1} + 15 kg Zn ha^{-1} along with BM at 20 DAE produced higher wheat biomass and harvest index. In experiment two, treatments were: four P-fertilizers sources (TSP, DAP, SSP, NP), four P levels (120, 90, 60, 0 kg P ha^{-1}) and three varieties of wheat (Shahkar-2013, Pirsabak-2013, and Atta-Habib-2010). The results indicated that maximum biomass yield and harvest index was calculted with SSP application. Maximum biomass and harvest index was produced with 120 kg P ha^{-1} application to the soil. Among wheat varieties Pirsabak-2013 perform better than others by producing higher harvest index and biomass.

Keywords: phosphorus, levels, sources, wheat, varieties, zinc levels, beneficial microbes

INTRODUCTION

Globally, among cereal crops in the world and also in Pakistan, wheat (*Triticum aestivum* L.) is the most important crop **(Tunio 2006; Malik 2006),** which is grown on about 37% cropped area. In Pakistani agricultural and GDP, wheat contributes considreble share (14.4%, 3%), respectively. Despite of being grown in larger area in the country, average yield of wheat at smallholder's fields is still far below the genetic potential of the crop **(Mann *et al.* 2004).** Accoreding to **Singh and Singh (2001)** that wheat crop is depliting soil fertility and also physical properties of the soil.
Productivity and growth of plant is affected by many enoronnametal and biotic factors **(Al-Rifaee *et al*. 2004; Musallam *et al.* 2004; Tawaha and Turk 2004; Turk *et al.* 2004; Al-Tawaha and Seguin 2006**). After nitrogen, Phosphorus stay 2nd key macro nutrient which have a key role in plant metabolisam (**Turk and Tawaha 2001; Tawah and Turk 2002b; Turk and Tawaha 2002; Turk *et al.* 2003; Nikus *et al.* 2004; Mehrvarz *et al*. 2008, imranuddin et al., 2017).** Most of Pakistani soil is low in avaliblie phosporus **(Nisar *et al*. 1992; Ahmad *et al.* 1992)**. For sustainable production P availability under semiarid condition is major problem **(Brady and Weil 2002).** Unlike nitrogen, phosphorus is relatively immobile in the soil. Unforutnalty, rainfed areas of Khyber Pakhtunkhwa have lack of optimum moisture low organic matter and low soil fertility **(Amanullah *et al*. 2009a; Amanullah *et al.* 2010a).** Pakistani soils have pH ranging from 7 to 9 with high calcium carbonate, which promate relatively insoluble dicalcium phosphate **(Hussain and Haq 2000).** High concentration of calcium compounds is responsible for decreasing phosphorus deficiency and decreasing crop yield **(Ibrikci *et al.* 2005).**
Phosphorus fertilzer availbe in the market in different types like TSP, DAP, SSP, MAP and NP. Among them DAP is imoprted other countries. Incase of micronutrients, Zn is play an important role in several physiological functions, plant metabolism and activation og enzymes **(Tisdale *et al.* 1984; Marschner 1995; Cakmak 2000).** Zinc deficiency affect sandy soils, calcareous, peat soils, high phosphorus soils and consider to be the wide spreed diffcency globally and also almost all crops **(Amanullah and Inamullah 2016).**
In semiarid climates P availability can be improved by application of beneficial microorganism (BM) **(Tripura *et al.* 2005; El-yazeid *et al.* 2007; Venkatashwarlu 2008; Walpola and Yoon 2012).** Beneficial microorganisms inceasere plant resistance toword disease and pest attack and improve crop growth **(El-yazeid *et al.* 2007).** Our recent published research indicates that beneficial microbes and thereby improve growth, yield and yield components in cereal crops e.g. in wheat **(Amanullah *et al.* 2016; Amanullah Khan 2017)** and maize **(Amanullah and Khalid 2016; Amanullah and Khan 2015).**
Different types soil bacteria and fungai are responsible for converting soil unavalible P into availpbe obe bu the relasing of different oganics compound which are acidic in anture, which decrease soil $_{p}$H and thereby increase phosphorus availability **(Walpola and Yoon 2012).** Use of microoganism is not only useful for higher crop production on susutaiblre bases but also decrease the use of chemical fertlizers. **(Hafeez *et al.* 2002).**
Keeping in view the job of phosphorus and zinc and helpful small scale life form application time, the present investigation was intended to consider the development and yield reaction of wheat verities to phosphorus, zinc and BMO for improving wheat efficiency in the examination region.

MATERIAL AND METHODS

Site description

Texture	clay loam	
P contents (Extractable)	6.57 mg kg^{-1}	Amanullah et al., (2009) and Amanullah et al., (2010)
Organic Matter	0.87%	
K contents (Extractable)	121 mg kg^{-1}	
pH	8.2	
Annaul Rainfall	300-500 mm	
Climate	Subtropical	

Two huge field experiments were conducted for studing the affect of phosphorus (P) levels and sources (S) on wheat during winter 2013-2015 at the University of Agriculture Peshawar, Agronomy Research Farm.

Treatments used in experiment one

Experiment one was carried out in winter 2013-14 (year one). The factors and their respective levels are;

Control = (No P and no Zn applied)

Factor (A): Phosphorous levels (kg ha^{-1})

P_1 = 40
P_2 = 60
P_3 = 80
P_4 =100

Factor (B): Zinc levels (kg ha^{-1}**)**

Zn_1 = 5
Zn_2 = 10
Zn_3 = 15

Factor (C): Beneficial microbes (BM) application Timings

EM_1 = At Sowing
EM_2 = 20 DAE (days after emergence)
EM_3 = 40 DAE

The experiment was worked out in RCBD with extention of split plot arrangement repeated 3 times. Combination of four P levels (factor A) and three Zn levels (factor-B) along with one control plot (no P and Zn applied) was used as main plot factors (4 x 3 = 12 + 1 = 13 main plots), and three BM application timing (factor C) as sub plots factor (13 x 3 = 39 total treatments per replication was used). Plot size of 2.4 m x 3.0 m having 8 rows was used for each treatment (39 x 3 = 117 sub-plots in the whole experiment two). DAP and $ZnSO_4$ was used as sources of P and Zn, respectively along with BIOAAB is a source of BM (12.5 liter ha^{-1}) were used. Urea was used is a soucre of N at the rate of (140 kg N ha^{-1}). Both the nutrinnts(P and Zn) was totally applied and incorotated in the soil during sowing time while N was apllied in two equal splits, half at sowing and half at 2nd irrigation. Wheat verity (siran) was sown at row to row distance of 3 cm at the rate of 120 kg ha^{-1}.

Experiment two

Experiment two was carried out in winter 204-15 (year two), with follwing factors

Control = (P zero application)

Factor (A): Sources of Phosphorous

S_1 = TSP
S_2 = SSP
S_3 = NP
S_4 = DAP

Factor (B): Levels of **Phosphorus (**kg ha^{-1}**)**

P_1 = 120
P_2 = 90
P_3 = 60

Factor (C): Wheat varieties

V_1 = Atta Habib-2010
V_2 = Shahkar-2013
V_1 = Pirsabak-2013

The expriemnt was workedt out in RCBD with extension of split plot arrangement. Four levels of P and three P sources along with one control plot (no P and Zn applied) was allotted to main plots (4 x 3 = 12 + 1 = 13 main plots) and factor-C (varieties) were allotted to sub plots (13 x 3 = 39 total treatments per replication was used). Plot size of 2.4 m x 3.0 m having 8 rows was used for each treatment (39 x 3 = 117 sub-plots in the whole experiment one). All of the studies veraity of wheat was sown at the rate of 120 kg ha^{-1} with row to row distance of 30 cm. The required P rates in the form of NP, TSP, DAP and SSP was incorporated in the soil during seedbed preparation at sowing.

Data recording and handling

Biological yield of wheat was calculted by the following formula.

$$\mathrm{BY(kg\ ha^{-1})} = \frac{\text{Wheat biomass in 4 central rows}}{\text{Rowlength}\,x\,\text{No.ofrows x Row} - \text{row distance}} \mathrm{x10000}$$

Grain yield (kg ha^{-1})

$$\mathrm{GY(kg\ ha^{-1})} = \frac{\text{Wheat grain yield in 4 central rows}}{\text{Row length}\ x\ \text{No.ofrows x Row} - \text{row distance}} \mathrm{x10000}$$

Harvest index (HI)

HI was calculated by the below mention equation

$$\mathrm{HI} = \frac{\mathrm{GY}}{\mathrm{BY}} \mathrm{x100}$$

Where as GY and BY stand for grain and biological yield, respectively

RESULTS AND DISCUSSION

Experiment # 1

Biomass

Data concerning biomass yield of wheat is shown in table 1 showed that zinc and phosphorous levels, Zn x P interaction and control vs rest was signifecnlty affected biomass f wheat. A considerable decrease in bomass of higher than 2000 kg ha^{-1} was calculated in compersion of control and treated plots (P znc Zn). Incase of P application highest biomass (11365 kg ha^{-1}) was recoreded when P was applied at the rate of 80 kg ha^{-1} which ws statiscally at par with 100 kg P ha^{-1} (11544 kg ha^{-1}), while at 40 kg ha^{-1} of P application lowest biomass (11039 kg ha^{-1}) was recoreded (Table 2). Zinc application at the rate of 15 kg ha^{-1} produced highest biomass (11039 kg ha^{-1}) while Zn appllication at the rate of 5 kg ha^{-1} produeced lowest biomass of wheat (10541 kg ha^{-1}) which was statistically at par with 10 kg Zn ha^{-1}. the interactive effect of both nutrunts showed that, increase both levels of the nutrient increase wheat biomass, the highest biomass of wheat (12354 kg ha^{-1}) was calculated when P ans Zn was applied at the rate of 80 and 15 kg ha^{-1}, respectively (Fig 1).

Table 1 Analysis of variance for total biomass yield (kg ha^{-1}) and harvest index (%) of wheat as affected by P and Zn level and EMO application timings in year one

		Total Biomass		Harvest index	
Source of variance	**D.F.**	**Probability**	**Significance**	**Probability**	**Significance**
Replications	{2}	--	--	--	--
Treatments	[12]	0.000	**	0.000	**
Zn	(2)	0.003	**	0.017	*
P	(3)	0.000	**	0.005	**
P x Zn	(6)	0.020	*	0.104	ns
Control vs. rest	(1)	0.000	**	0.000	**
Error I	**{24}**	--	--	--	--
EMO timings	{2}	0.278	ns	0.748	ns
Treatments x EMO	[24]	0.969	ns	0.909	ns
Control vs. rest x EMO	(2)	0.275	ns	0.192	ns
Zn x EMO	(4)	0.747	ns	0.873	ns
P x EMO	(6)	0.961	ns	0.868	ns
Zn x P x EMO	(12)	0.915	ns	0.816	ns
Error II	**{52}**	--	--	--	--
Total	**116**	CV1= 5.2%	CV2= 4.8%	CV1= 5.7%	CV2= 6.7%

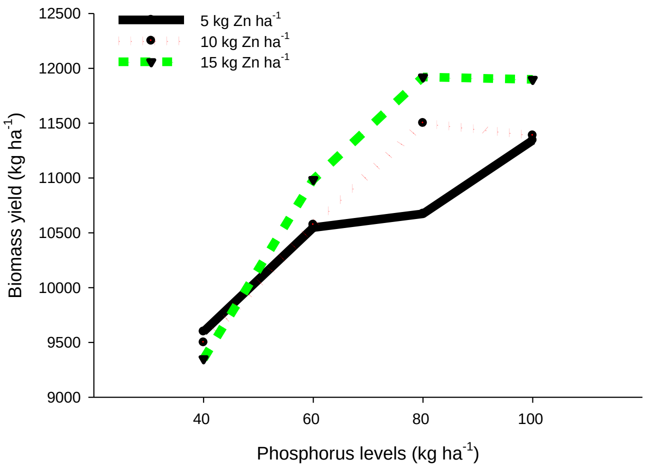

Figure 1 Interactive effect of phosphorus and zinc on biomass yield (kg ha^{-1}) of wheat in year one (Exp. 1).

Harvest index (HI)

HI of wheat was signifeclty afftected by Zn,P, P x Zn and control vs rest (table 1). Time of application of benifical microoraginsim and thair interactions were not signifeclty harvest index of wheat. Treated plots (P and Zn application) produced higher harvest index (39.5 %) as comperad with control plots (34.1%). Incase of P application, highest harvest index was recoreded when 80 kg P ha^{-1} was applied as compared with all other P levels which produced statistically the same but lower harvest index (Table 2). Zn application at higher rate (15 kg ha^{-1}) produed higher harvest index (40%) which was statisticaly at par with 10 kg ha^{-1} while the lowest harvest index (38.5 %) was calculated for 5 kg Zn ha^{-1} (Table 2).

Table 2 Biomass yield (kg ha^{-1}) and harvest index (%) of wheat as affected by phosphorus (P), zinc (Zn) and effective microorganism (EMO) application timings in year one

P levels kg ha^{-1}	Biological yield (kg ha^{-1})	Harvest index (%)
40	9483 c	38.9 b
60	10702 b	38.8 b
80	11365 a	41.0 a
100	11544 a	39.4 b
Significance	**	**
Zinc levels (kg ha^{-1})		
5	10541 b	38.5 b
10	10741 b	39.9 a
15	11039 a	40.0 a
Significance	**	*
EMO timings		
Emergence	10761	39.3
20 DAE	10877	39.8
40 DAE	10683	39.4
Significance	Ns	ns
Control	8607	34.1
Rest	10774	39.5
Interactions		
Zn x P	*(Fig. 1)	ns
Zn x EMO	Ns	ns
P x EMO	Ns	ns
Zn x P x EMO	Ns	ns

Experiment # 2

Biomass yield

Different souces of P and P levels as well as control vs rest signifectly affected wheat biomass, while all of thair interaction was found not signifecnt. Incase of control vs rest highest biomass was produced in treated plots (10704 kg ha^{-1}) as compered with control plots (9525 kg ha^{-1}). incase of P sourecs highest biomass was produed (10852 kg ha^{-1}) when SSP was used as sourese of P, which was statisticaly at par with application of NP as sourece of P (10735 kg ha^{-1}), while application of DAP produed lowest biomass of wheat (10568 kg ha^{-1}) (Table 2). incase of P application, hihest biomass was produec when P was applied at 120 kg ha^{-1}, followed by 90 kg P ha^{-1} (10657 kg ha^{-1}), while application of 60 kg ha^{-1} prouded lowest biomass of wheat (10391 kg ha^{-1}). Although the differences in biomass varieties were not-significant, yet variety Pirsabak-2013 ranked first by producing the highest biomass (10776 kg ha^{-1}), as compered with Shahkar-2013 and Atta-Habib which produed lower biomass of wheat (10724 kg ha^{-1}, 10776 kg ha^{-1}), respectively (Table 4).

Table 3 Analysis of variance for biomass yield (kg ha^{-1}) and harvest index of wheat varieties as affected by phosphorus sources and their levels in year two

		Total Biomass		**Harvest index**	
Source of variance	**D.F.**	**Probability**	**Significance**	**Probability**	**Significance**
Replications	{2}	--	--	--	--
Treatments (Tr)	[12]	0.000	**	0.000	**
P levels	(2)	0.000	**	0.000	**
P Source	(3)	0.000	**	0.008	**
PL x PS	(6)	0.439	ns	0.963	*
Control vs. Rest	(1)	0.000	**	0.000	**
Error I	**{24}**	--	--	--	--
Varieties	{2}	0.051	ns	0.000	**
Treatments x varieties	[24]	0.751	ns	0.285	ns
Control vs. rest x varieties	(2)	0.008	ns	0.093	ns
PL x Varieties	(4)	0.883	ns	0.110	ns
PS x Varieties	(6)	0.801	ns	0.322	ns
PL x PS x Varieties	(12)	0.984	ns	0.720	ns
Error II	**{52}**	--	--	--	--
Total	**116**	CV1= 7.6%	CV2= 5.7%	CV1= 2.2%	CV2= 2.3%

Harvest index

Harvest index of wheat had sigifeclty affected by P sourecs, levels as well as control vs rest (table 3). All the interaction was found not signifecnt except PL x PS. Higher harvest inde was calculated in treated plots (35.41%) as compared with control (32.37%). Incase of P sorces, highest harvest index (35.8%) was produed in SSP applied plots, which statistical simialar with NP, while apllivation of Dap produced lowe harvest index (34.8%) as mention in table 4. Among the P levels, P application at the rate of 120 kg ha^{-1} produced ighest harvest inex (36.7%) which was statistcaly simialr with application of 90 kg P ha^{-1}, followed by 60 kg P ha^{-1}. in case of verital compersion Pirsabak-2013, performe better in tarm of harvest index followed by Atta-Habib-2010 which was statisticaly similar with Shahkar-2013 (35.2 % and 34.8 %), respectively.

The PL x PS showed that phosphorus from single super phosphate at two higher levels increased the harvest index of wheat varieties as compared at other sources at lower levels (Fig. 2).

Table 4 Biomass yield (kg ha-1) and harvest index (%) of wheat varieties as affected by phosphorus sources and their levels in year two

Phosphorus Sources	Biological yield (kg ha-1)	Harvest index (%)
SSP	10852 a	35.8 a
TSP	10662 bc	35.2a b
DAP	10568 c	35.0 b
NP	10735 ab	35.6 a
Significance	**	**
Phosphorus levels (kg ha-1)		
60	10391 c	33.2 b
90	10657 b	36.3 a
120	11064 a	36.7 a
Significance	**	**
Varieties		
Pirsabak 2013	10776 a	36.2 a
Shahkar 2013	10724 a	35.2 b
Atta-Habib 2010	10682 a	34.8 b
Significance	ns	**
Control	9525 b	32.37 b
Rest	10704 a	35.41 a
Interactions		
PL x PS	ns	*(Fig. 2)
PL x Varieties	ns	Ns
PS x Varieties	ns	Ns
PL x PS x Varieties	ns	Ns

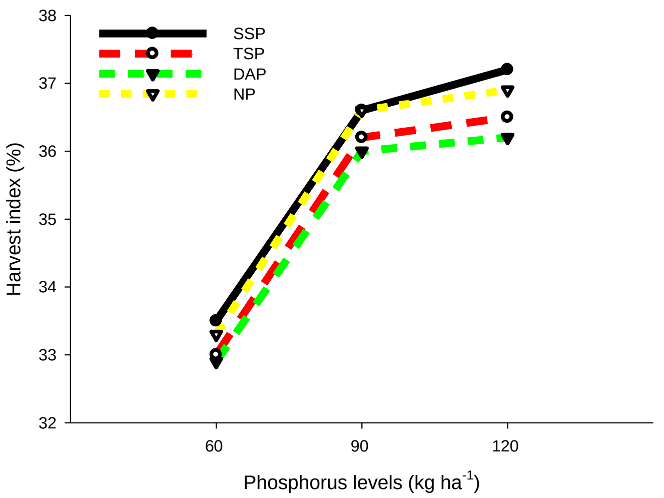

Figure 2 Interactive effect of phosphorus levels and sources on harvest index (%) of wheat in year two (Exp. 2).

DISCUSSION

Control vs. Rest

The improvement in biomass yield in the rest (treated plots) over control was attributed to the increase in plant height, leaf area indexleaves plant^{-1}, and yield components. From our recent prievius research **(Amanullah *et al.* 2014)** we have concluded that tretated plots have suffincet plant ntruntrint which contribute to increase plant height, leaves plant^{-1} and leaf area, as well as higher yield and yield components and so had higher biomass yield over control plots. The phosphorus treated plots in wheat produced 8.8 % more dry matter m^{-2} over control **(Amanullah *et al.* 2015).**

Increase in harvest index of wheat in the rest (treated plots) over control was contributed to the improvement in crop growth, yield components, grain yield and especially more dry matter partitioning into the wheat reproductive parts (spikes). According to **Amanullah *et al.* (2015),** proper phosphorus nutrition for wheat partitioned more DM into the spikes (59%) than its stem (21%) and leaf (20%). The phosphorus treated plots partitioned about 7.5% more dry into the spike than control **(Amanullah *et al.* 2015).**

Phosphorus levels

Application of higher P level produced tillers density of wheat, leaf number and area, plant height, grains spike^{-1} and ultimately the biomass yield **(Khan *et al.* 2009**; **Lu and Barber 1995).**

Higher rate of P inmprove wheat harvest index, it might be due P contributuion in yield and yield components. Similar results was also reported by **Saber *et al.* (2010)** who stated that higher rate of P increase wheat crop grain yield and harvest index. P applicatiion increase grain spike^{-1} **Memon et al. (2011)** and **Rahim et al. (2010)** which will contribut to final yield (**Amanullah *et al.*** **2014**). In our recent research on rice (**Amanullah and Inamullah 2016),** we obtained maximum harvest index (41.4%) was calculated for the highest P level of 120 kg P ha^{-1} while the minimum harvest index (36.3%) was achieved in control plots.

Phosphorus source

In experiment 2, it was indicated that various phosphatic fertilizers had significant effect on biological yield and harvest index of wheat crop. Among the different phosphorus fertilizers SSP application had produced the highest biological yield and harvest index which was similar to TSP and NP while DAP produced lowest yield which possibly because of high availability of P, which contribute in early root and growth development. **Khan et al. (2010)** reported that SSP application performed better in term of productivity as compared to other P sources (DAP, TSP and NP). **Reddy and Sigh (2003)** also reported that SSP produced higher crop yield followed by by NP and DAP.SSP treted plot higher yield as compared with NP and DAP, which passibly the additional affect of Sulphur which improved P availability to plants in SSP **Ali *et al.* (2015).**

Phosphorus and beneficial microbes interaction

The increase in BY due to application of BM probably the release of maximum plant nutrients from organic sources of soil especially P, higher photosynthetic rate **(Xu *et al.* 2001; Sangakkara and Weerasikara. 2001). Amanullah *et al.* (2014)** reported that application of beneficial microbes improved spikes m^{-2} and grains spike^{-1} that produced higher biological yield. Because beneficial microbes application improve plant nutrients availability, especially of P which produced higher growth and production **(Soylu *et al.* 2004; Afzal *et al.* 2005; Tripura *et al.* 2005; Walpola and Yoon 2012).** PSB + FYM along with P levels improved root developement, tillaeing and plant dry weight (**Zhang *et al.*, 1996**). Application of the highest BM level improved yield and yield components (Amanullah et al., 2014) and thereby increased harvest index in wheat. **Dobblaere *et al.* (2002)** reported that wheat growth can be improved by application of BM, which increase grain spike^{-1} and grain yield^{-1}. **Khan *et al.* (2010)** also reported that increase in grain yield increase the harvest index. According to **Chaturvedi (2006)** phosphate-solubilizing bacteria and FYM application increase wheat plant height, tiller m^{-2}, leaf weight, grain yield, P, N and P uptake.

Phosphorus and zinc interaction

In the current study P x Zn interaction was found significant which showed that biomass yield increase with the increase in the levels of both nutrients. **Arshad *et al*. (2016**) reported that higher biomass was produced by P application at the rate of 90 kg ha^{-1} combine with 10 kg Zn ha^{-1} **Jan et al. (2013).** Apllication of 90 kg P ha^{-1}was applied produced higher biomass of wheat. Similar results was also reported by **Potarzycki and Grzebisz (2009). Alam *et al.* (2005)** aslo repsorted that P application increase dry matter yield of wheat crop.

The interaction between Zn and P was studied earlier by many scientists, however, many results were inconsistent **(Orabi *et al.* 1985). Shang and Bates (1987)** found that P increased Zn deficiency in corn without Zn treatments, and Zn increased P deficiency in plants without P treatments, however, deficiency may be recover with the application of suitable nutrient. P combine with Zn and forming water non soluble zinc-phosphate compounds in soil solutions, which decrease the uptake of Zn by the plant roots and Zn translocation in the plant plant (**Robson and Pitman, 1983); Kizilgoz and Sakin (2013). Burleson *et al.* , (1961; Zhao *et al.*, (2007); Kacar and Katkat (2011)** the all reported that application of P increase P uptake by the plant but decreae Zn upatke by the plant which causing difeciency of Zn. In calcareous soils P application increased adsorption of Zn and calcium carbonate which are responsible for adsorption of Zn **(Sead 2004). Li *et al.*, (2003)** reported that P application increase plant dry matter and P contents.

CONCLUSION

We concluded from our two years research that application of 100 kg P ha^{-1} + 15 kg Zn ha^{-1} along with beneficial microbes when applied at 20 days after emergence increased biological yield and harvest index (experiment one). In experiment two, the results showed that the higher biological yield and harvest index was obtained with application of an acidic P-fertilizer "single super phosphate" when applied at the highest P rate (120 kg P ha^{-1}). among wheat varieties ranked first was Pirsabak-2013 by producing high yield and HI in the study area.

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