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Improving Wheat Productivity in Calcareous Soils through Band Replacement of Farmyard Manure with Phosphorus

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ABSTRACT

An experiment on band placement of farmyard manure (FYM) with different phosphorus levels on productivity of wheat was conducted under arid climates during 2005-06 and 2006-07. The crop was sown as per farmyard manure (FYM) treatments viz: 120, 180 and 240 kg ha^{-1}, while phosphorus (P) levels were 60, 90 and 120 kg P_2O_5 ha^{-1} in calcareous silty loam soil applied in band (line). Data revealed that band placement of FYM along with P application increased the total dry matter produced as well as grain yields of wheat. The crop receiving 120 kg ha^{-1} P along with 240 kg ha^{-1} FYM gave the maximum grain yields. Application of FYM with higher rates of P application resulted in early maturity (by 15 days) of the crops as compared with lower P rates in these studies. P application along with FYM had a positive influence on number of fertile tillers m^{-2}, 1000-grain weight and leaf area index. The crop receiving 120 kg ha^{-1} P with 240 kg ha^{-1} FYM had maximum grain yields of 4.26-4.45 t ha^{-1} during two crop seasons.

Key Words: Productivity; Grain yield; Wheat; FYM; Phosphorus; Calcareous soils

INTRODUCTION

The soils of Pakistan are calcareous and insufficient data is available about the behavior of phosphorus (P) in the calcareous soils (Ahmad & Rashid, 2003). Nisar (1985) reported that the utilization efficiency of phosphatic fertilizer by crops is very low and the recovery is also from 15 to 25%. Low recovery of applied P is due to various reactions taking place in the soil. Superphosphate applied to alkaline calcareous soil is converted to insoluble calcium phosphate (49 to 59%), iron and aluminum phosphate (14 to 19%), while the water-soluble fraction ranges from 5 to 9% only (Ahmad *et al*., 1992). The plant tissue recovered only 11 to 19% of the applied P (Sharif, 1985). Chaudhry and Qureshi (1980) reported average phosphorus fixation of 71,62, 56,29 and 29% of added P in clay, clay loam, loam, sandy loam and loamy sand soils, respectively after one month of incubation. One of the reactions leading to phosphorus retention in calcareous soils is fixation of phosphate by clay of 1:1 type saturated with calcium (Tisdale *et al*., 1997). However, the soils of Pakistan contain 2:1 type clay and phosphorus fixation capacity of these soils is not reported phosphorus fixing capacity (Memon & Fox, 1983; Nisar, 1988). However, low P requirement with increasing clay content may be due to the buffering capacity of clay soil, which renews the P concentration in solution (Olsen & Watanab, 1970).

Farm yard manure (FYM), on an average contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O (Motsara, 1987). It is estimated that about 1.5 mt of nutrients are available from FYM and of this quantity, N accounts for 0.0726 mt, P 0.0191 mt and K for about 0.0617 mt (Ahmad & Rashid, 2003). Application of FYM adds nutrients to the soil and thus reduces the total dependence on chemical fertilizer increases P availability (Guar, 1990). The application of organic material helps the microorganisms to produce polysaccharides, which improve the soil structure (Guar, 1994). Organic manures not only act as a source of plant nutrients and energy for microorganisms but also influence the availability of native nutrients (Hedge & Dwivedi, 1993; Parr & Hornick, 1995). In addition organic manure improves water holding capacity and permeability of the soil (Hussain & Khan, 2000; Hussain *et al*., 2004).

The availability of P can be increased if it is mixed with FYM. Since it enhances availability and efficiency of P and increases wheat yield. According to Ahmad *et al*. (1992) superphosphate mixed with FYM in 1:2 ratios increased the efficiency of P significantly. Similarly, Sharma and Prasad (1984) Sharma *et al*. (1987) and Sharif (1985) reported that SSP mixed with FYM in 2:1 ratio increased the P availability and yield of wheat. The practice of mixing increased the efficiency by 30-40%, which means that an area normally requiring three bags of superphosphate will need only two bags. Similarly Sharif and Chaudhry (1985) reported 21% and 24% increase in wheat grain yield when fertilizer was premixed with FYM both at low and high levels of fertilizer application. This technique could be effective only if the quality of FYM used for mixing is good

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and with a narrow C: N ratio. Many other researchers also concluded that chemical fertilizers when mixed with organic fertilizers not only improved physical condition of soil but also influenced the availability of native nutrients (Hedge & Dwivedi, 1993).

Studies show that that DAP and SSP mixed with FYM gave significant yield increases (Shakir *et al*., 1992). Rashid *et al.* (1994) concluded that the maximum grain yield was achieved when full dose of fertilizer was applied followed by EM and FYM. However, when combination of FYM+EM was applied yield was significantly higher than full dose of fertilizer. Suri and Puri (1997) and Vyas *et al*. (1997) reported a marked influence of different combinations of P and FYM on wheat yield. The treatment FYM+NP in 2:1 was the optimum for most of the parameters. Rao *et al*. (1998) reported that combination of FYM and P increased wheat yield, uptake of P and available P was also increased in plots receiving the combination of both organic and inorganic fertilizer. Sahu *et al*. (1999) in a field experiment found that 50% rock phosphate and 50% FYM gave the maximum yield of wheat. The grain yield was increased when NPK and FYM was applied together (Singh *et al*., 1999). Similarly Singh and Verma (1999) in a trail conducted with application of FYM along with recommended dose of chemical fertilizer reported the maximum yield of wheat.

This study was planned and conducted on a calcareous soil to determine the interactive effects of P and FYM on the agronomic performance of wheat to get maximum yield.

MATERIALS AND METHODS

This study was conducted at the Experimental Farm, University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan, (latitude= 30.15^o N 544, longitude= 71.30^o E 885, altitude = 126.6 m) during 2005-2006 and 2006-2007. According to textural classification soil was silty loam with the following physio-chemical characteristics: sand 28-26%, silt 54-56% and clay18-17%, saturation 39-37%, pH 8.08-8.10, EC (dS m^{-1}) 3.00-3.09, organic matter content from 0.69 to 0.76% and N 0.04-0.05%, P_2O_5 5.25 to 5.5 ppm, K_2O 250-300 ppm, Zn 0.38-0.36 and $CaCO_3$ 9.0-9.1% in the two growing seasons. The levels of applied P were P_1=60, P_2=90 and P_3=120 (kg P_2O_5 ha^{-1}) and of FYM: F_1=120, F_2=180 and F_3=240 (kg ha^{-1}) in band placement (application in line), because of low quantity used in respective plots. Application of FYM was done just after sowing of the crop as per treatment. The experiment was laid out in randomized complete block design with split plot arrangement keeping P levels in main plots and FYM levels in sub-plot, each measuring 1.6 x 6 m.

Wheat (*Triticum aestivum* L. cv. Inqulab-91) was sown on a well prepared seed bed on November 10 during the two cropping seasons with the help of a single row hand drill in 20 cm spaced rows using seed rate of 125 kg ha^{-1}. A basal dose of (N) and (K) each at the rate of 57 and 65 kg ha^{-1} was applied in the form of urea and potassium sulphate, respectively. P was applied in the form of single superphosphate. The whole of P and K along with half dose of N was applied at sowing, while the remaining half of N was top-dressed with first irrigation. First irrigation was applied three weeks after sowing the crop, while subsequent irrigations were applied as and when needed. In all five irrigations each of 7.5 cm depth excluding pre-soaking irrigation (*Rauni*) were applied from sowing to harvesting during both years. Logran ext. 64 WG (Terbutryn + triasulfuron) @ 250 g ha^{-1}and Topik 15 WP (Clodinafop propargyl + cloquinitocet mexyl) @ 250 g ha^{-1} herbicides were used to control broad and narrow leaved weeds each after 1st and 2nd irrigation, respectively at optimum soil moisture conditions to avoid weed-crop competition. All other agronomic practices were kept normal and uniform. Data on biological yield (total biomass of plant above ground), grain yield, plant height, number of fertile tillers, days taken to maturity were taken at harvesting time whereas 1000-grain weight, number of grains per spike, harvest index at crop harvest and leaf area index were recorded at 90 DAS.

The data were statistically analyzed by using the computer statistical program MSTAT-C (Freed & Scott, 1986). Analysis of variance was made to test the overall significance of the data, while the least significance difference (LSD) test at P=0.05 was used to compare the differences among treatment means.

RESULTS

Application of phosphorus and FYM significantly affected the number of fertile tillers in these studies. In the first year, P level of 120 kg P_2O_5 ha^{-1} produced significantly higher number of fertile tillers (275 m^{-2}) than 90 and 60 kg P_2O_5 ha^{-1}, which differed significantly from each other and produced 270 and 265 tillers m^{-2}, respectively. Similar trend was observed during the 2nd year (Table I). Although application of 240 kg ha^{-1} FYM gave significantly greater number of fertile tillers (272 m^{-2}) but was at par with 180 kg ha^{-1} FYM (270 m^{-2}) and minimum number of tillers were recorded with 120 kg ha^{-1} FYM. During 2nd year, fertile tillers increased gradually with each increase of FYM level (Table II). The interactive and main effects of P and FYM on plant height of wheat were significant during each year. Application of P @120 kg P_2O_5 produced maximum plant height (94.80 cm) of all treatments (Table I). Maximum plant height was noted at 240 kg ha^{-1} FYM, but a minimum one (91.30 cm) at 120 kg FYM ha^{-1}. Crop fertilized with 120 kg P_2O_5 along with 240 kg ha^{-1} FYM attained maximum plant height (96.00 cm). It was followed by 120 kg P_2O_5 along with 180 kg ha^{-1} FYM. However, a minimum plant height (89.28 cm) was recorded in case of 60 kg P_2O_5 with 120 kg ha^{-1} FYM (Table III).

Table I. Effect of phosphorus application on the performance of wheat in calcareous soils

Phosphorus Levels	No. of fertile tillers	Plant height (cm)	No. of grains spike^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Leaf area index	Days taken to maturity
P_1 (60 kg ha^1)									
2005-06	265c	89.67c	45ns	38.36c	3.40c	8.67c	39.96ns	4.60c	146a
2006-07	269c	89.78c	44	38.41c	3.62c	8.95c	40.02	4.64c	146a
Mean	267c	89.72c	44	38.39c	3.51c	8.81c	39.99	4.62c	156a
P_2 (90 kg ha^1)									
2005-06	270b	92.05b	45	39.55b	3.63b	9.15b	40.03	4.72b	141b
2006-07	273b	92.13b	45	39.59b	3.83b	9.51b	40.03	4.76b	142b
Mean	271b	92.09b	45	39.57b	3.73b	9.33b	40.03	4.74b	142b
P_3 (120 kg ha^1)									
2005-06	275a	94.78a	46	40.45a	4.15a	10.31a	39.98	4.88a	137c
2006-07	279a	94.82a	46	40.35a	4.34a	10.64a	40.53	4.92a	138c
Mean	277a	94.80a	46	40.40a	4.24a	10.48a	40.07	4.90a	137c
LSD									
P_1	1.666	1.109	ns	0.145	0.001	0.032	ns	0.045	2.38
P_2	1.666	0.173	ns	0.105	0.002	0.063	ns	0.055	2.81

Any two means not sharing a letter differ significantly at (P=0.05)
Note: *P_1 and **P_2 denote for LSD values for year 2005-06 and 2006-07 respectively

Table II. Effect of farmyard manure application on the performance of wheat in calcareous soils

FYM Levels	No. of fertile tillers	Plant height (cm)	No. of grains spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Leaf area index	Days taken to maturity
FYM_1 (120 kgha^1)									
2005-06	268b	91.23c	45	39.11c	3.64c	9.18c	39.97	4.69c	144a
2006-07	272c	91.38c	45	39.12	3.83c	9.48c	40.03	4.73b	144a
Mean	270c	91.30c	45	39.12c	3.74c	9.33c	40.00	4.71c	144a
FYM_2 (180 kgha^1)									
2005-06	270a	92.21b	46	39.47b	3.73b	9.39b	40.01	4.73b	141b
2006-07	274b	92.26b	45	39.46	3.92b	9.71b	40.04	4.76b	142b
Mean	272b	92.23b	45	39.47b	3.83b	9.55b	40.02	4.74b	142b
FYM_3 (240 kgha^1)									
2005-06	272a	93.06a	45	39.78a	3.81a	9.56a	39.99	4.78a	139c
2006-07	275a	93.08a	46	39.78a	4.04a	9.91a	40.03	4.83a	140c
Mean	273a	93.07a	46	39.78a	3.92a	9.74a	40.01	4.81a	140c
LSD									
P_1	1.329	0.121	ns	0.109	0.001	0.038	ns	0.027	1.79
P_2	1.329	0.149	ns	0.077	0.027	0.061	ns	0.047	1.79

Any two means not sharing a letter differ significantly at (P=0.05)
Note: *P_1 and ** P_2 denote for LSD values for year 2005-06 and 2006-07, respectively

Table III. Effect of combined application of phosphorus and farmyard manure application on the performance of wheat in calcareous soils

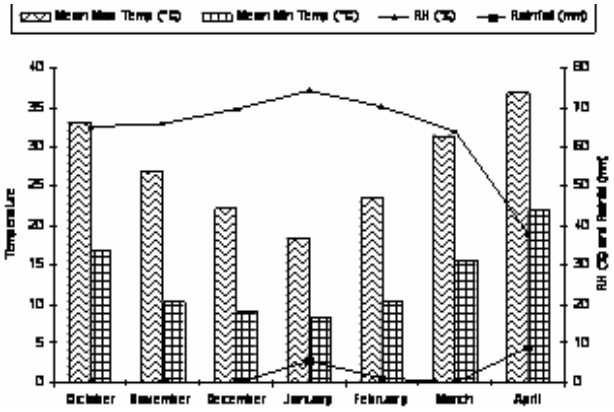
Phosphorus and FYM Levels	No. of fertile tillers	Plant height (cm)	No. of grains spike^{-1}	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Leaf area index	Days taken to maturity
P_1 FYM_1	266	89.28i	44	37.81e	3.46h	8.72i	39.96	4.59	149a
P_1 FYM_2	267	89.63h	44	38.64d	3.49h	8.10h	40.05	4.70	146b
P_1 FYM_3	268	90.26g	45	38.71d	3.58g	8.89g	39.97	4.83	144c
P_2 FYM_1	270	91.05f	45	39.48c	3.65f	9.14f	40.03	4.61	143cd
P_2 FYM_2	272	92.28e	45	39.57c	3.70e	9.28e	40.03	4.74	142de
P_2 FYM_3	273	92.95d	46	39.66c	3.83d	9.58d	40.02	4.88	141ef
P_3 FYM_1	275	93.59c	45	40.06b	4.09c	10.12c	40.02	4.65	140f
P_3 FYM_2	277	94.80b	46	40.18b	4.28b	10.57b	39.99	4.77	138g
P_3 FYM_3	279	96.00a	46	40.97a	4.36a	10.74a	40.04	4.99	135h
LSD	ns	0.135	ns	0.16	0.032	0.028	ns	ns	1.72

Any two means not sharing a letter differ significantly at (P=0.05)

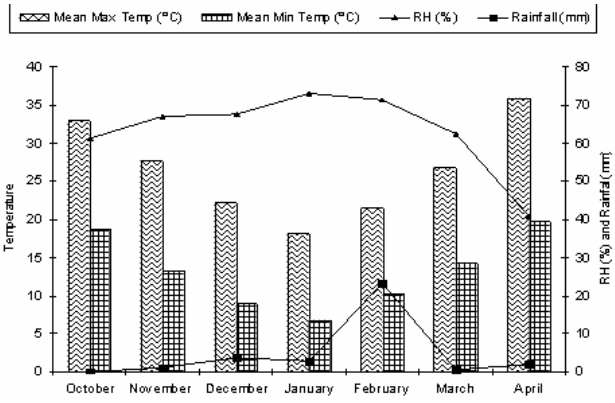
Number of grains per spike on an average ranged from 44-46 and 45-46, under different levels of P and FYM, respectively. The interactive effects of P and FYM on grains per spike were also non-significant (Table III). Main effects of P and FYM and their combinations on 1000-grain weight were significant (P=0.01). P application at 90 and 120 kg ha^{-1} improved 1000-grain weight whereas a minimum grain weight of 38.39 g observed for 60 kg ha^{-1}. Increased levels of FYM had a positive bearing on improving 1000-grain weight from 39.12 to 39.78 in these studies (Table II). Crop receiving 120 kg ha^{-1} P_2O_5 with 240 kg ha^{-1} FYM produced higher grain yield than rest of the treatments. By contrast, a

Fig. 1. Meteorological data for growing period of crops (October-April)during the year 2005-2006 (A) and 2006-2007 (B) showing rainfall and temperature fluctuation and relative humidity

(A). Year 2005-2006



(B). Year 2006-2007



minimum 1000-grain weight (37.81 g) was recorded at 60 kg ha^{-1} P_2O_5 along with 120 kg ha^{-1} FYM (Table III).

Application of FYM with P had a positive bearing (P=0.01) upon wheat grain yield. On an average application of P increased grain yield with 90 and 120 kg ha^{-1} P as compared with 60 kg ha^{-1} that recorded grain yield of 3.40 and 3.62 t ha^{-1} during 2005-2006 and 2006-2007 respectively (Table I). Similar trends were observed for increasing levels of FYM but the relative increase in grain yield was only (4.8%) with increasing levels of FYM to 180 to 240 kg ha^{-1} as compared with 120 kg ha^{-1} (Table II). Combined application had a pronounced influence (P=0.01) upon the application of increasing levels of both P and FYM (Table III). Application of 120 kg P_2O_5 in combination with 240 kg ha^{-1} FYM produced significantly the highest grain yield (4.36 t ha^{-1}), whereas minimum grain yield (3.46 t ha^{-1}) was recorded for the crop fertilized with 60 kg P_2O_5 with 120 kg ha^{-1} FYM.

The individual effects of P and FYM as well as their combinations on biological yield were significant ($P < 0.05$) during both the years. Application of FYM at 120 kg ha^{-1} yielded lowest biological yield (9.18-9.48 t ha^{-1}) during two cropping seasons. Increasing FYM up to 180 and 240 kg ha^{-1} increased biological yield over the lowest level during both the years. Increased P also linearly increased biological yield (9.33-10.48 t). Band placement with increased levels of FYM with P significantly ($P < 0.01$) influenced the biological yield (Table III). Interactive and main effects of P and FYM on harvest index (HI) of wheat were non-significant during each year. During both the years, different levels of P in combination with varying quantities of FYM failed to record significant increase in HI (Table III). Mean values of HI ranged from 39.96 to 40.04% under the various P and FYM treatments.

During both the years increase in LAI (4.5-4.9) was recorded up to 90 days after sowing, which declined sharply thereafter presumably due to senescence of leaves towards maturity. Application of P and FYM significantly ($P < 0.05$) enhanced LAI development during both the years. During 2005-2006, the crop fertilized with 120 kg P_2O_5 ha^{-1} exhibited the maximum LAI (Table I). Similarly there was a progressive increase in LAI with each increment of FYM from 120 to 240 kg ha^{-1} on an average the maximum LAI of 4.81 at 240 kg ha^{-1} FYM and the minimum of 4.71 at 120 kg ha^{-1} FYM (Table II).

The main effect of P and FYM and their interaction on days taken to maturity was significant. On an average during both the years application of P at 90 and 120 kg ha^{-1} lead to earlier maturity (142-137 d) as compared with 60 kg ha^{-1} (Table I). Likewise FYM reduced the time taken to maturity. However relative values were 142 and156 days with the later two levels of FYM in these studies as compared with 120 kg ha^{-1} (Table II). The crop fertilized with 120 kg ha^{-1} P_2O_5 along with 240 kg ha^{-1} FYM matured earlier by 135 d, while this duration was longer (149 d) at 60 kg P_2O_5 along with120 kg ha^{-1} FYM. In general, higher doses of P and FYM hastened the maturity of the crop as compared to their lower doses.

DISCUSSION

The final yield of wheat is directly proportional to the productive tillers m^{-2} at harvest. Number of fertile tillers varied significantly (P=0.05) across the years and more number of tillers were recorded during second year of study. This may be due to more favorable agro climatic conditions. In this study higher levels of P or FYM produced maximum productive tillers as compared to lower levels. The interaction between phosphorus and FYM in respect of fertile tillers m^{-2} was, however, non-significant. These results corroborate the findings of Bukheh *et al.* (1992) and Hussain *et al.* (2004).

Likewise, there was a significant year effect on plant height of wheat showing relatively taller plants during 2005-2006 might be due to better environment. Application of P and FYM and their interaction on plant height was significant. Higher levels of both P and FYM produced

taller plants as compared to their lower levels and their combined effect was also positive on plant height. Favorable and promotive effects of these factors on plant height of wheat may be due to better development of root system and nutrient uptake. The same results were also reported by Khan *et al.* (2005) and Hussain *et al.* (2004 & 2008).

Slightly positive effects of P and FYM on grains per spike of wheat were recorded but the difference was not reached to the level of significant. This might be due to the reasons that this character is mostly controlled genetically. The same results were reported by Bukheh *et al.* (1992) and Hussain *et al.* (2004 & 2008), who observe slightly increase in number of grains per spike with the application of P and FYM. There was a significant increase in grain weight of wheat with each increment of P from 90 to 120 kg ha^{-1} by 3 and 5%, respectively as compared to the lowest level of 60 kg ha^{-1} in this study. Application of FYM also had a positive bearing by 1-2% only over its lowest level 120 kg FYM ha^{-1}. Grain yield of wheat varied significantly over years giving about 9.41% higher grain yield during 2005-2006. This difference might be attributed to variations in daily mean temperatures across the years, more total rainfall during the second year, different patterns of relative humidity and other temporal variation in the environment (Fig. 1A & B). On an average application of P increased grain yield by 12.5 and 17.5% with 90 and 120 kg ha^{-1} P as compared with 60 kg ha^{-1}. Similar trends were observed for increasing levels of FYM but the relative increase in grain yield was only 2-4% with increasing levels of FYM to 180 to 240 kg ha^{-1} as compared with 120 kg ha^{-1}. Response of P in terms of grain yield was improved significantly when it was accompanied by increased levels of FYM. Dhindwal *et al.* (1992) reported that P and FYM application markedly increased wheat grain yield in normal soils. Alam *et al.* (2003) reported that application of P increased dry matter yield irrespective of its source.

In this study increasing levels of P improved biological yield by 11-16% when its dose was increased from its lowest application level (60 kg ha^{-1}). Increasing FYM up to 180 and 240 kg ha^{-1} increased biological yield by 2 and 4%, respectively over the lowest level during both the years, which is similar to the findings of Saeed *et al.* (1998) and Hussain *et al.* (2004). Effect of P and FYM and their interaction on harvest index (HI) was Non-significant in the present case, which corroborates the data of Hussain *et al.* (2004).

LAI of wheat which on an average was relatively higher in the 2nd year than the previous year might be due to better environmental conditions. During both the years, maximum LAI were recorded at 90 days after sowing, which declined thereafter. Application of P and FYM significantly (P = 0.05) enhanced LAI development. Leaf area index was linearly increased with each increment of P and FYM from lower levels to maximum level. Increase in LAI as a result of P and FYM application was also reported by Parr and Hornick (1995).

On an average during both the years application of P at 90 and 120 kg ha^{-1} lead to early maturity of the crop by 5 and 9 days, respectively as compared with 60 kg ha^{-1}. FYM also reduced the time taken to mature the crop. However, the relative values were only by 3 and 5 days with the later two levels of FYM in these studies as compared with 120 kg ha^{1}. Differential response of the wheat to various levels of P and FYM with regards to days taken to maturity has also been reported previously by Gupta (2003) and Hussain (2007).

CONCLUSION

On an average application of P increased grain yield by 12.5 and17.5% with 90 and 120 kg ha^{-1} P. There was only 2-4% increase with increasing levels of FYM to 180 to 240 kg ha^{-1}. The highest wheat grain yield of 4.26 and 4.45 t ha^{-1} was recorded for the combination of 120 kg ha^{-1} P_2O_5 and 240 kg ha^{-1} FYM for 2005-06 and 2006-07, respectively.

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