Growth and Productivity of Oats (*Avena sativa* L.) as Influenced by Fly Ash and Phosphorous Levels in Indo-Gangetic Plains of India

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ABSTRACT

Background: Dairy farming is one of the oldest and well established subsidiary occupation and most widely adopted by all over farming community of Punjab state. Every farmer, if wish to start any entrepreneurship along with agriculture-First Think upon Dairy Farming. The latest training, new techniques and research work help in making this business work better. There is a need for substantial increase in the current yield of green fodder to provide complete and good quality feed to the animals. The current study aimed to study the effect of fly ash and phosphorous on the growth and fodder and grain yields of dual purpose oats.

Methods: Field experiments were conducted at Research Farm, College of Agriculture, Guru Kashi University, Talwandi Sabo, Bathinda to study the effect of different levels of fly ash and phosphorous on growth and productivity of oats during *rabi* seasons in 2018-19 and 2019-20. The trial was laid out in split plot design with three levels of fly ash (0, 5 and 10 t ha^{-1}) in main plot and four phosphorous levels (0, 10, 20 and 40 kg P_2O_5 ha^{-1}) in sub plot, replicated thrice.

Result: Fly ash @ 10 t ha^{-1} recorded highest plant height, dry matter accumulation, leaf area index, number of effective tillers/m row length, number of seeds/spike, 1000-grain weight, grain yield, straw yield and biological yield than control and 5 t ha^{-1}. The per cent increase of grain yield in fly ash @ 10 t ha^{-1} was 8.69 and 18.11 over 5 t fly ash ha^{-1} and control, respectively. Phosphorous @ 40 kg P_2O_5 ha^{-1}resulted in higher growth characters, yield attributing characters and productivity of oats. Phosphorous @ 40 kg P_2O_5 ha^{-1} (21.35 q ha^{-1}) and 20 kg P_2O_5 ha^{-1} (20.87 q ha^{-1}) treatments produced statistically similar grain yield of oats. Phosphorous @ 20 and 40 kg P_2O_5 ha^{-1} recorded 20.29 and 23.05% higher grain yield than 0 kg P_2O_5 ha^{-1}, respectively. Application of P_2O_5 @ 40 kg ha^{-1} along with application of fly ash @ 5 and 10 t ha^{-1} produced statistically similar fodder yield of oats. The highest grain yield (22.97 q ha^{-1}) was recorded in plots treated with the application of P_2O_5 @ 40 kg ha^{-1} along with the application of fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and application of fly ash @ 10 t ha^{-1}. The highest grain yield (22.97 q ha^{-1}) was recorded in plots applied with P_2O_5 @ 40 kg ha^{-1} along with fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and fly ash @ 10 t ha^{-1}.

Key words: Fodder yield, Fly ash, Grain yield, Leaf area index, Oats, Phosphorous.

INTRODUCTION

Dairy is growing with very first speed, but our farmer is not moving with the same speed. As the requirement of nutritionist to high yield is very high, because of high milk yield and environmental stress to our dairy animals. The cheaper and easily available sources of nutrient to lactating animals are green fodder which is abundantly available in our farmer's field. The cost of dairy farming especially for milk production is very high, if we are rearing animals alone on feed/grains. Dairy feed costs 70-75% and the green fodder's contribution is significant. Animal husbandry is an old business, but recent training, new techniques and research work help in making this profession work better. The present number of cattle in Punjab is about 81.2 lakh, which has 62.4 lakh big animals. There is a need for substantial increase in the current yield of green fodder to provide complete and good quality feed to the animals. One animal gets 30.65 kg of fodder rate per day, which is very low. If 40 kg of green fodder is found in a large livestock daily, then there is an annual requirement of 911 million tonnes of green fodder. There is enough time when our farm has huge quantity of green fodder, but it conserves this supply as hay is one of our target. Hay making not alone conserve this aboundance supply, but also ensure the regular supply of nutritious product for the whole year.

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Oats (*Avena sativa* L.) is an important winter cereal crop in north-western regions of India due to congenial climate for this crop in these regions owing to its excellent growth habit, quick re-growth after cutting and high nutritive value for both milch and draught livestock so its popularity as fodder crop is increasing. The oat crop is known to have high yielding potential and multi-cut ability. Oats form an excellent combination when fed along with other winter legumes like *berseem*, lucerne, *senji* and *shaftal*. Oats is rich in total digestible nutrients, protein, fat, vitamin B_1 and minerals such as phosphorus and iron. It is used for human consumption as well as feed for animals (Hussain *et al.,* 2003). In South-west district of Punjab due to poor quality of underground water *berseem* is not performing well so, farmer are shifted to cultivation of multi-cut oats.

Oats was produced in 10.2 million ha area with an annual production of 233.0 million tonnes in the world. In India, cultivated fodder is limited to 4.9% of the total cropped area. The total area under cultivated fodders is 8.6 million ha on individual crop basis. The total area covered under oats cultivation in the country is about 1.0 million ha with 35-50 t/ha green fodder productivity (Anonymous, 2021). In India, it is grown in Punjab, Haryana, Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra and West Bengal. It constitutes 30 per cent of the Indian market in terms of volume for breakfast foods next only to Cornflakes and 18 per cent in value terms. High grain yield is the most desired characteristic of oat cultivars. Most of the fodder crops are grown under irrigated situations except in areas, which receive adequate winter rains. Under such situations where water supply is limited and the farmers are not in a position to grow the crops having high water requirement such as Lucerne and berseem, oat can grow successfully, which provides energy rich nutritious and palatable fodder for livestock.

Fly ash is produced as a by-product of burning coal in thermal power plants and its production in India will exceed 200 MT by 2020 (Kalra *et al.,* 1996). Fly ash amendment in soil improves K, Ca, Mg and S status of deficient soil (Deshmukh *et al.,* 2000, Gaind and Gaur, 2003), however N and P deficient soil could be restored by the co application of fly ash and microbial inoculants. In present era, soil deterioration due to excessive usage of chemical fertilizers has been already reported for which application of organic materials are strongly recommended as an alternative supplement to chemical fertilizers so as to retain soil productivity. Fly ash has been evaluated for possible use as carrier for *Azotobacter* and *Azospirillum* formulation in wheat crop to reduce the application of chemical fertilizers (Kumar and Singh, 2010). Fly ash has also been used for neutralization of acidic mine spoils and restoration of nutrient balance in alkaline wastelands (Jala and Goyal, 2006). In conjunction with organic manure and microbial inoculants, fly ash enhances plant biomass production from degraded soils. Chemical fertilizers are one of the major nutrient suppliers besides organic and green manures, despite excessive use of chemical fertilizers, the gap between the nutrient removal and replenishment is significantly high.

Phosphorus (rates and mode of application) determine plant reproductive efficiency and play a vital role in growth and development of crop. Phosphorus (P) is the second major essential nutrient element for crop growth and good quality yield. The most obvious effect of P is on the plant root system. The requirement of P in nodulating legumes is higher compared to non-nodulating crops as it plays a significant role in nodule formation and fixation of atmospheric nitrogen (Brady and Well, 2002). Due to the important role played by P in the physiological processes of plants, application of P to soil deficient in this nutrient leads to increase yield. Rao and Shaktawat (2002) noticed that application of 3 levels P_2O_5 @ 20, 40 and 60 kg ha^{-1} along with 3 levels of gypsum that is 0 kg ha^{-1}, 250 kg ha^{-1} at basal (sowing) and 125 kg ha^{-1} at sowing and 125 kg ha^{-1} at flowering significantly increased the available nutrients at post harvest soils. In view of the particulars, the present study was carried out to find out the effect of fly ash and phosphorous on the growth and fodder and grain yields of dual purpose oats.

MATERIALS AND METHODS

The present investigation entitled “Growth and productivity of oats (*Avena sativa* L.) as influenced by fly ash and phosphorous levels in Indo-gangetic plains of India” was carried out at experimental area of research farm of Guru Kashi University, Talwandi Sabo (Bathinda) during *rabi* 2018-19 and 2019-20. Talwandi Sabo (Bathinda) is situated at 29°33′ N latitude and 74°38′ E longitude at a height of 208 metres above the mean sea level. The experimental site belongs to semi-arid climate, where both summers and winters are acute. A maximum temperature of about 45°C is common during summer, while freezing temperature accompanied by frost happening may be there in the months of December and January.

The soil of the experimental field was loamy sand in texture and slightly alkaline in reaction’s the soil was poor in organic carbon, low in available nitrogen and medium in phosphorus but high in available potassium. Plant height (cm) at spikelet formation, dry matter accumulation at harvest, leaf area index at 120 days after sowing was recorded in oats. Leaf area area was calculated by using following formula:

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

Green fodder was cut at height of 5 cm from the ground after 60 days after sowing. Green fodder yield from net plot was weighed and converted into q/ha.

Yield attributing characters (effective tillers, number of grains/ear and 1000-seeds weight were recorded at maturity. Grain yield was recorded from the net plot after harvest. The plants from the net plot area were harvested, tagged and bundled plot wise. The harvest was dried under sun to a standard moisture condition and weighed for bundle weight. The harvest was threshed to seed. The seed yield per plot (kg per plot) was then converted into seed yield per hectare (q ha^{-1}). The harvested material from net area of each plot was thoroughly sun dried. After drying, the producer of individual net plot area was threshing and the weight recorded straw per plot. The straw yields per plots (kg plot^{-1}) were then converted into straw yield per hectare (q ha^{-1}). The harvest index (HI) was calculated from both the seed and straw yield with the following formula:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield (Grain yield + Straw yield)}} \times 100$$

The experiment were performed in continue two years. Analysis of variance was performed using Proc GLM procedure of SAS version 9.4 (SAS. 2017) and significant mean differences were tested using Fisher's protected least significant difference (LSD) test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Growth attributes

Plant height was significantly affected by fly ash and phosphorous levels at spikelet formation. The maximum plant height (179.2 cm) was recorded in 10 t ha^{-1} fly ash which was significantly higher than control (175.8 cm), but it was statistically at par with fly ash @ 5 t ha^{-1} (Table 1). This might be due to favourable changes in physical and microbiological properties of soil and also due to addition of considerable amounts of essential nutrients to soil by fly ash. The significant increase in micronutrient content in fly ash amended soil was also reported by Deshmukh *et al.* (2000).

Plant height (180.4 cm) was higher under 40 kg P_2O_5 ha^{-1}, which was significantly higher than control and 20 kg P_2O_5 ha^{-1} and it was statistically at par with 30 kg P_2O_5 ha^{-1}. This consummate effect of P fertilization on growth of oats might be due to it decisive role in voluminous root development which facilitate the crop to excerpt water and minerals from deeper zones. These results corroborate with the findings of Singh *et al.* (2006) and Tomar *et al.* (2013).

A perusal of data showed that dry matter accumulation fly ash @ 10 t ha^{-1} was recorded highest dry matter accumulation (152.2 q ha^{-1}), which was significantly higher than control (141.7 q ha^{-1}) and 5 t ha^{-1} (146.9 q ha^{-1}) (Table 1). This might be due to favourable changes in physical and microbiological properties of soil and also fly ash adds considerable amounts of essential nutrients to soil. The addition of fly ash in sandy soils as a replacement of P and K fertilizer increased the dry matter production of clover (Summers *et al.,*1998). The significant increase in micronutrient content in fly ash amended soil was also reported by Deshmukh *et al.* (2000).

The effect of phosphorus on the dry matter accumulation of oats was found to be positive and significant. The highest dry matter accumulation was recorded under P_2O_5 applied at the rate of 40 kg ha^{-1}, which was significantly higher than control and 10 kg ha^{-1} and but it was statistically at par with 20 kg P_2O_5 ha^{-1}. The increases in dry weight due to P application may be attributable to the fact that P is known to help in the development of more extensive root system and nodulation and thus enables plants to absorb more water and nutrients from depth of the soil. This in turn could enhance the plant's ability to produce more assimilates which were reflected in the high dry weight. Similar results have been reported by El- Habbasha *et al.* (2005) and Gobarah *et al.* (2006).

A perusal of data (Table 1) show that increasing levels of fly ash increase leaf area index. Highest leaf area index (3.35) was observed with fly ash @ 10 t ha^{-1}, which was statistically at par with fly ash @ 5 t ha^{-1} and it was significantly higher than control. The increase in enzyme activity might be due to increased microbial population as the fly ash with extreme fineness and more than 1 per cent organic carbon could serve as good medium for their growth and proliferation was reported by Lal *et al.* (1996).

The highest leaf area index was found in 40 kg P_2O_5 ha^{-1}, being statistically at par with 20 kg P_2O_5 ha^{-1} and significantly higher than control (0 kg P_2O_5 ha^{-1}) and 10 kg P_2O_5 ha^{-1}. It may also be due to the fact that optimum availability of phosphorous has been associated with increased rapid growth and development, thus those plots which received optimum phosphorous produced more number of branches/ plant as compared to control plots.

Table 1: Effect of fly ash and phosphorous levels on growth parameters of oats (pooled data of 2 years).

Treatments	Plant height (cm)	Dry matter accumulation (q ha^{-1})	Leaf area index
Fly ash levels (t ha^{-1})			
0	175.8	141.7	2.83
5	178.5	146.9	3.13
10	179.2	152.2	3.36
LSD (P=0.05)	1.4	4.5	0.26
Phosphorus levels (kg ha^{-1})			
0	174.7	128.9	2.69
10	177.1	142.8	3.01
20	179.0	156.4	3.25
40	180.4	159.6	3.46
LSD (P=0.05)	2.1	8.5	0.28

Fodder yield

Perusals of data showed that green fodder yield significantly improved with the fly ash and phosphorous levels (Table 2). The green fodder yield was improved with the application of fly ash. The maximum green fodder yield was recorded with the application of 10 t ha^{-1} fly ash which was significantly higher than 0 and 5 t ha^{-1} fly ash. Green fodder yield increased significantly with the increase in phosphorous levels. Highest green fodder yield was observed in treatment having 40 kg P_2O_5 ha^{-1} phosphorous which was significantly higher than other phosphorous treatments. The lowest green fodder yield was observed in control treatment. Such a positive yield response of phosphorus application in obvious when it is deficient in the growing medium. The soil samples analyzed before start of the experiment also showed that the available phosphorus status of the soil in the experimental site was in medium range (32 kg P_2O_5/ha). The highest fodder yield was recorded in plots treated with the application of P_2O_5 @ 40 kg ha^{-1} along with the application of fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and application of fly ash @ 10 t ha^{-1} and application of fly ash @ 5 t ha^{-1} with 40 kg P_2O_5 ha^{-1}. The lowest fodder yield was recorded with P_2O_5 @ 0 kg ha^{-1} along with phosphorous @ 0 kg P_2O_5 ha^{-1}.

Table 2: Fodder yield of oats as influenced by fly ash and phosphorous levels (pooled data of 2 years).

Fly ash levels (kg ha^{-1})	Fodder yield (q/ha) Phosphorous levels (kg P_2O_5 ha^{-1})				Mean
	0	10	20	40	
0	118.0	130.2	136.2	153.9	134.6
5	132.5	142.5	149.4	166.2	147.7
10	145.9	160.4	166.9	182.7	164.0
Mean	132.1	144.4	150.8	167.6	148.7

CD (p=0.05). Fly ash levels (F): 12.3; Phosphorous levels (P): 15.1; Interaction (F×P): 20.5.

Yield attributes of oats

The highest number of effective tillers/meter row length (118.7) was recorded with fly ash @ 10 t ha^{-1}, which was statistically at par with fly ash @ 5 t ha^{-1} and it was significantly higher than control (Table 3). This might be due to favourable changes in physical and microbiological properties of soil and also fly ash adds considerable amounts of essential nutrients to soil. The application of fly ash in the soil increases the soil structure by improving the porosity, increasing the depth of penetration of the plant root system and enhancement of soil water-holding capacity (Kene *et al.,* 1991).

The effect of different levels of phosphorus was significant on number of effective tillers/m row length. The highest number of effective tillers/meter row length (118.6) was recorded with 40 kg P_2O_5/ha, which was significantly higher than control, 10 and 20 kg P_2O_5/ha. The interaction effect between different fly ash and phosphorous levels showed that non-significant effect on number of effective tillers/m row length of oats.

A perusal of data (Table 3) showed that different fly ash and phosphorous levels had significant effect on number of grains/ear of oat. The number of grains/ear increased with increase fly ash levels. The highest number of grains/ear (111.6) was recorded at fly ash @ 10 t ha^{-1} application and it was significantly higher than control and 10 t fly ash ha^{-1}. The significant increase in micronutrient content in fly ash amended soil was also reported by Deshmukh *et al.* (2000).

Application of graded level of phosphorus significantly upgraded the number of grains/ear in oats. The highest number of grains/ear (111.9) was recorded in 40 kg P_2O_5 ha^{-1} treatment and it was significantly higher than 0 and 10 kg P_2O_5 ha^{-1} treatments, but it was statistically at par with 20 kg P_2O_5 ha^{-1}. The interaction effect between different fly ash and phosphorous levels showed that non-significant effect on number of grains/ear of oats

The data showed a significant effect of different levels of fly ash on 1000-seed weight of oat (Table 3). There was

Table 3: Effect of fly ash and phosphorous levels on yield parameters of oats (pooled data of 2 years).

Treatments	No. of effective tillers per m row length	No. of grains/ ear	1000-grain weight (g)
Fly ash levels (t ha^{-1})			
0	107.7	102.6	23.2
5	115.3	106.7	24.0
10	118.7	111.6	24.8
LSD (P=0.05)	3.8	4.3	1.0
Phosphorus levels (kg ha^{-1})			
0	108.3	99.7	22.3
10	113.3	106.0	23.1
20	115.3	110.1	24.9
40	118.6	111.9	25.7
LSD (P=0.05)	2.2	3.1	1.3

increase in 1000-grain weight progressively as increase in fly ash quantity. The highest 1000- grain weight (24.8 g) was recorded with fly ash @ 10 t ha^{-1}, which was statistically at par with fly ash @ 5 t ha^{-1}, but it was significantly higher than control. This might be due to favourable changes in physical and microbiological properties of soil because application of fly ash in the soil increases the soil structure by improving the porosity, increasing the depth of penetration of the plant root system and enhancement of soil water-holding capacity (Kene *et al.,* 1991).

The highest 1000-grain weight was recorded with the application of 40 kg P_2O_5 ha^{-1} which was significantly higher than 0 and 10 kg P_2O_5 ha^{-1} but it was statistically at par with 20 kg P_2O_5 ha^{-1}. The propitious outcome was due to regulatory function of P in photosynthesis that escalates carbohydrate accumulation and sugar metabolism. It also coordinates starch: sucrose ratio and governs proper mobilization of photosynthates that lead to increased 1000-seed weight. Similar results were also reported Biswas *et al.* (2009) and Khan *et al.* (2017). Interaction effect between fly ash and phosphorous levels with respect to 1000-grain weight found to be non-significant.

Productivity of oats

Grain yield increase with increased fly ash applied of crop (Table 4). The highest grain yield (21.52 q ha^{-1}) was recorded in fly ash @ 10 t ha^{-1} which was significantly higher than control and 5 t ha^{-1}. This might be due to favourable changes in physical and microbiological properties of soil and also fly ash adds considerable amounts of essential nutrients to soil. The fly ash application increased the seed grain yield of *kharif* and *rabi* crops during their respective seasons of growth (Kuchanwar *et al.* (1997). Similar results of increased growth and yield of plants in soil and composts amended with fly ash have been reported (Prasad *et al.,* 2000).

Further perusal of the data revealed that grain yield of oats varied significantly due to phosphorous levels. The highest grain yield (21.35 q ha^{-1}) was obtained in 40 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.,* 0 kg P_2O_5 ha^{-1} (17.35 q/ha) and 10 kg P_2O_5 ha^{-1} (19.81 q/ha), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (20.87 q/ha). Higher grain yield obtained in higher level of phosphorous which might be due to the promotion effect of P fertilization on growth parameters like plant height, dry matter, number of branches was attributed to better development of root system and nutrient absorption led to higher yield attributes. The increases in dry weight due to P application may be attributable to the fact that P is known to help in the development of more extensive root system and nodulation and thus enables plants to absorb more water and nutrients from depth of the soil. This in turn could enhance the plant's ability to produce more assimilates which were reflected in the high pod yield. Similar results have been reported by El-Habbasha *et al*. (2005) and Gobarah *et al.* (2006).

The interaction effect between fly ash and phosphorous levels on grain yield was found to be significant (Table 5). The highest grain yield (22.97 q ha^{-1}) was recorded in plots treated with the application of P_2O_5 @ 40 kg ha^{-1} along with the application of fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and application of fly ash @ 10 t ha^{-1}. The lowest grain yield (15.75 q ha^{-1}) was recorded in plots treated with P_2O_5 @ 0 kg ha^{-1} along with phosphorous @ 0 kg P_2O_5 ha^{-1}.

The data showed an increase in straw yield with each increment of fly ash (Table 4). The highest straw yield (105.8 q ha^{-1}) was obtained at fly ash @ 10 t ha^{-1}, which was statically at par with fly ash @ 5 t ha^{-1} (102.4 q ha^{-1}) and it was significantly higher than control. This might be due to favourable changes in physical and microbiological properties of soil and also fly ash adds considerable amounts of essential nutrients to soil. Selvakumari *et al.,* (2000) reported that better supply of nutrients, conductive physical environment leading to better aeration, root activity and nutrient absorption and the consequent complementary effect owing to FA application would have resulted in higher straw and grain yield of rice.

Table 4: Effect of fly ash and phosphorous levels on grain yield, straw yield, biological yield and harvest index of oats (pooled data of 2 years).

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Fly ash levels (t ha^{-1})				
0	18.22	96.2	114.4	15.91
5	19.80	102.4	122.2	16.19
10	21.52	105.8	127.3	16.89
LSD (P=0.05)	1.10	3.5	4.1	NS
Phosphorus levels (kg ha^{-1})				
0	17.35	91.7	109.0	15.90
10	19.81	103.3	123.1	16.08
20	20.87	105.1	125.9	16.56
40	21.35	105.7	127.1	16.78
LSD (P=0.05)	0.80	1.1	3.0	NS
Interaction	1.02	NS	NS	NS

Table 5: Grain yield of oats as influenced by fly ash and phosphorous levels (pooled data of 2 years).

Fly ash levels (kg ha^{-1})	Grain yield (q/ha)				
	Phosphorous levels (kg P_2O_5 ha^{-1})				Mean
	0	10	20	40	
0	15.75	18.25	19.15	19.71	18.22
5	17.36	19.50	20.96	21.36	19.80
10	18.94	21.68	22.49	22.97	21.52
Mean	17.35	19.81	20.87	21.35	19.84

LSD (P=0.05) Fly ash levels (F): 1.10; Phosphorous levels (P): 0.80; Interaction (F×P): 1.02.

Straw yield of oats varied significantly due to phosphorous levels. The highest straw yield (105.7 q ha^{-1}) was obtained in 40 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.,* 0 kg P_2O_5 ha^{-1} (91.7 q ha^{-1}) and 10 kg P_2O_5 ha^{-1} (103.3 q ha^{-1}), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (105.1 q ha^{-1}). The interaction effect between fly ash and phosphorous levels on straw yield was found to be non-significant.

The biological yield in oats was significantly influenced by different levels of phosphorus (Table 4). The highest biological yield (127.3 q ha^{-1}) was obtained at fly ash @ 10 t ha^{-1}, which was statically at par with fly ash @ 5 t ha^{-1} (122.2 q ha^{-1}) and it was significantly higher than control. Biological yield of oats varied significantly due to phosphorous levels. The highest biological yield (127.1 q ha^{-1}) was recorded in 40 kg P_2O_5 ha^{-1} which was significantly higher than other phosphorous levels *viz.,* 0 kg P_2O_5 ha^{-1} (109.0 q ha^{-1}) and 10 kg P_2O_5 ha^{-1} (123.1 q ha^{-1}), but it was statistically at par with 20 kg P_2O_5 ha^{-1} (125.9 q ha^{-1}). The interaction effect between fly ash and phosphorous levels on biological yield was found to be non-significant.

The data pertaining to the harvest index showed that different fly ash levels had non-significant effect on harvest index of oats (Table 4). The data indicated that harvest index increase with increased fly ash applied of crop. The maximum harvest index (16.89%) was recorded at fly ash @ 10 t ha^{-1}. However, minimum harvest index was recorded (15.91%) in control. This might be due to favourable changes in physical and microbiological properties of soil and also fly ash adds considerable amounts of essential nutrients to soil (Selvakumari *et al.,* 2000). Different phosphorous levels had non-significant effect on harvest index of oats. However, the highest harvest index was observed in 40 kg P_2O_5 ha^{-1}. Interaction effect between fly ash and phosphorous levels with respect to harvest index in oats found to be non-significant.

CONCLUSION

Application of fly ash and phosphorous significantly enhanced the growth, yield attributes and grain yield in oats. The per cent increase of grain yield in fly ash @ 10 t ha^{-1} was 8.69 and 18.11 over 5 t fly ash ha^{-1} and control, respectively. Phosphorous @ 40 kg P_2O_5 ha^{-1} (21.35 q ha^{-1}) and 20 kg P_2O_5 ha^{-1} (20.87 q ha^{-1}) treatments produced statistically similar grain yield of oats. Phosphorous (P_2O_5) @ 20 and 40 kg ha^{-1}recorded 20.29 and 23.05% higher grain yield than 0 kg P_2O_5 ha^{-1}, respectively. The highest grain yield (22.97 q ha^{-1}) was recorded in plots treated with the application of P_2O_5 @ 40 kg ha^{-1} along with the application of fly ash @ 10 t ha^{-1} and it was statistically at par with 20 kg P_2O_5 ha^{-1} and application of fly ash @ 10 t ha^{-1}.

REFERENCES

Anonymous (2019). Ministry of Agriculture, Govt. of India. www.indiastat.com.

Biswas, P., Bhowmick, M. and Bhattacharya, A. (2009). Effect of molybdenum and seed inoculation on nodulation, growth and yield in urdbean [*Vigna mungo* (L.) Hepper]. Journal of Crop and Weed. 5(1): 141-144.

Brady, N.C. and Weil, R.R. (2002). The Nature and Properties of Soils. (13th Ed.), Pearson Education Pvt. Ltd., Indian Branch, Singapore. Pp 311.

Deshmukh, A, Matte, D.B. and Bhaisare, B. (2000). Soil properties as influenced by flyash application. Journal of Soils and Crops. 10: 69-71.

El-Habbasha, S.F., Kandil, A.A., Abu-Hagaza, N.S., Abd-El-Haleem, A.K., Khalfallah, M.A. and Gh. Behairy, T. (2005). Effect of phosphorus levels and some biofertilizers on dry matter, yield and yield attributes of groundnut. Bulletin of Faculty of Agriculture, Cairo Univ ersity. 56: 237-252.

Gaind, S. and Gaur A.C. (2003). Quality assessment of compost prepared from fly ash and crop residue. Bioresour. Technology. 87: 125-127.

Gobarah, M.E., Mohammad, M.H. and Tawfik, M.M. (2006). Effect of phosphorus fertilizer and foliar spraying with zinc on growth, yield and quality of groundnut under reclaimed sandy soils. Journal of Applied Science Research. 2: 91-496

Hussain, I., Khan, M.A. and Ahmad, K. (2003). Effect of row spacing on the grain yield and the yield component of wheat (*Triticum aestivum* L.). Journal of Agronomy. 2: 153-159.

Jala, S. and Goyal, D. (2006). Fly ash as a soil ameliorant for improving crop productiona review. Bioresour. Technology. 97(9): 1136-1147.

Kalra, N., Joshi, H.C., Chaudhary, R., Choudhary, A., Pathak, H. and Jain, M.C (1996). Impact of fly ash on environment and Agriculture. The Botanica. 46: 177-181.

Kene D.R., Hanjewar, S.A, Ingaole, B.M. and Chapale, S.D. (1991). Effect of application of fly ash on physic-chemical properties of soil. Journal of Soils and Crops. 1(1): 11-18.

Khan, M.M.S., Singh, V.P. and Kumar, A. (2017). Studies on effect of phosphorous levels on growth and yield of *Kharif* mung bean [*Vigna radiata* (L.) Wilczek]. International Journal of Pure and Applied Biological Sciences. 5(4): 800-808

Kuchanwar, O.D., Matte, D.B. and Kene, D.R. (1997). Evaluation of graded doses of fly ash and fertilizers on nutrient content and uptake of groundnut grown on vertisol. Journal of Soil Pollution. 87: 93-110.

Kumar, A. and Singh, B.P. (2010). Effect of row ratio and phosphorus levels on performance of chickpea (*Cicer arientinum*)-Indian mustard (*Brassica juncea* L.) intercropping. Indian Journal of Agronomy. 51: 100-102.

Lal, J.K., Mishra, B. and Sarkar, A.K. (1996). Effect of fly ash on soil microbial and enzymatic activity. Journal of Indian Society of Soil Science. 44: 77-80.

Prasad, B.K., Banerjee, S.K. and Roy, H. (2000). Effect of fly ash amendment on germination behaviour and seedling survival on certain cultivated legumes. Environmental Ecology. 18: 210-216.

Rao, S.S. and Shaktawat, M.S. (2002). Residual effect of organic manure, phosphorus and gypsum application in preceding groundnut (*Arachis hypogaea*) on soil fertility of productivity of Indian Mustard (*Brassica juncea*). Indian Journal of Agronomy. 47(4): 487-494.

Selvakumari, G., Baskar, M., Jayanthi, D. and Mathaw, K.K. (2000). Effect of integration of flyash with fertilizers and organic manures on nutrient availability, yield and nutrient uptake of rice in Alfisols. Journal of Indian Society of Soil Science. 48: 268-278.

SAS. (2017). Version 9.4. Inc Cary (NC, USA.): SAS Institute.

Singh, J., Rao, M.R., Punit, M.K. and Mayee, C.D. (2006). Impact of soil depths on yield of Bt cotton hybrids under rainfed conditions. Journal of Cotton Research and Development. 20(1): 80-82.

Summers, R., Clarke, M., Pope, T. and O'Dea, T. (1998). Western Australian fly ash on sandy soils for clover production. Communication in Soil Science and Plant Analysis. 29: 2757-2767.

Tomar, T.S., Kumar, S. and Tomar, S. (2013). Effects of plant density, nitrogen and phosphorus on black gram [*Vigna mungo* (L.) hepper]. Annals of Agricultural Research. 34(4): 430-432.