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RESEARCH ARTICLE

Crop performance, weed dynamics and economics of summer groundnut as influenced by paddy straw mulching and levels of phosphorus in Southern Odisha

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Abstract

Paddy straw is an organic mulch that lowers evaporation, inhibits the growth of weeds and improves soil properties. Phosphorus is the second major essential nutrient element required by the plant after nitrogen. It facilitates the proper development of the crop's roots, which in turn aids in the greater uptake of water and nutrients from the soil, ultimately enhancing plant growth and production. The objective of the study was to study the effect of paddy straw mulching and phosphorus on the crop performance, weed dynamics and the economics of summer groundnut. The present study was conducted at Post Graduate Research Farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Odisha in 2022. The experiment was laid out in split plot design with 12 treatments and 3 replications. Paddy straw mulching was taken in the main plot and the levels of phosphorus were taken under subplots. Phosphorus was applied as basal at the time of sowing. Results indicated that paddy straw mulch at 5 t ha^{-1} smothered the weeds more effectively and recorded significantly the lowest total weed density (8.4 No.m^{-2}) and total weed dry weight (6.28 g m^{-2}). Maximum pod (2376 kg ha^{-1}) and kernel yield (1726 kg ha^{-1}) of groundnut were recorded from paddy straw mulch at 5 t ha^{-1} which were 14.72 % and 22.32 % higher than no mulch treatment. Among the levels of phosphorus, 60 kg P_2O_5 ha^{-1} recorded significantly higher pod (2447 kg ha^{-1}) and kernel yield (1936 kg ha^{-1}) which were 26.39 % and 35.41 % higher than no phosphorus application. Application of 60 kg P_2O_5 ha^{-1} also recorded the lowest weed density and dry weight. Application of 5 t ha^{-1} paddy straw mulch and 60 kg P_2O_5 ha^{-1} was found to be the best treatment combination increasing pod and kernel yield of groundnut, decreasing total weed density as well as total weed dry matter and resulting in maximum economics.

Keywords: groundnut; paddy straw mulching; phosphorus; pod yield; weed dynamics.

Introduction

Groundnut (*Arachis hypogaea* L.) is the 13th most important food crop and one of the world's most productive economic crops, which is rich in oil and protein (1, 2). Groundnut is an annual oilseed crop, which belongs to Leguminosae (Fabaceae) family and Papilionoideae sub family. Groundnut is a self-pollinated crop. Its inflorescence is present on leaf axils of both primary and secondary branches, it may be simple or compound depending on botanical types. 2-5 flowers are present in each inflorescence and flower colour varies from yellow to orange or rarely dark orange to garnet (3). This crop bears underground fruit, which is known as pod (4). Groundnut seeds contain 6% water, 11.5% carbohydrates, 2.3% ash, 38 - 50% oil and high amounts of Vitamins B and E (5). Groundnut is named as the 'King of oilseed crops', which strengthens the agricultural economy in India (6). In India, the area, production and productivity of groundnut are 6.09 M ha, 10.21 MT and 1676 kg ha^{-1} respectively (7). It also fixes atmospheric Nitrogen and improves soil fertility as a leguminous oilseed crop. Gujarat is the highest producer of groundnut, which contributes 46% of total groundnut output annually in India (6). In south Odisha, groundnut can be grown in all the 3 agronomic season viz., kharif, rabi and summer. Summer groundnut need more irrigation due to high temperature and scarcity of rainfall (8). Mulching in crop field is an important agronomic practice for improving yield and soil protection. There are different materials which can be used as mulching material *viz.*, different crop residues, plastic films, pebbles, gravel, crushed stone, biological geotextiles etc (9). Organic mulch maintains soil moisture by reducing evaporation, regulates soil temperature, improves soil properties and fertility status to enhance growth and productivity of crops (8). Use of different bio-mulches also showed higher crop yield, water use efficiency and monetary return by improving soil physio-chemical and biological properties by enhancing soil fertility status (10). The original soil moisture is maintained and weed growth is considerably reduced by paddy straw mulching (11). Mulching offers extra benefits for preserving soil moisture, controlling temperature, reducing salinity, eliminating weeds and improving soil aggregation (12). Phosphorus (P) is the second most important nutrient for crop growth and high-quality output. Soils contain phosphorus in both organic and inorganic forms and the proportions of each form differ significantly amongst soils. Organic P is usually unavailable for plant uptake due to its strong binding to soil colloids, as long as it is broken down and released during the mineralisation process (13). Phosphorus is available to plants in its inorganic forms ($H_2PO_4^-$ and HPO_4^-), although soil solution contains very little of it (14). In soils, the chemistry of P cycling is highly complicated and greatly influenced by temperature and moisture. Out of all the available forms of phosphorus, labile P, needs to be supplemented regularly to meet plants' nutrient needs at every stage of their growth cycle. The amount of phosphorus in the soil solution is increased by applying inorganic P fertilisers (15). Phosphorus is a vital component in cell molecules including phospholipids, nucleic acids and adenosine triphosphate (ATP). P is essential for all plant functions, including crop maturation, photosynthesis, nitrogen fixation and root development (16). Better root system of the plant is where phosphorus has the most evident impact (17). Due to the involvement of phosphorus in nodule development and atmospheric nitrogen fixation (by increasing nitrogenase activity), nodulating legumes have higher phosphorus requirements than non-nodulating crops (18). Phosphorus significantly contributes to plant physiological processes and adding phosphorus to soil increases groundnut productivity (19, 20). Mulching helps in moisture retention in the soil which helps in phosphorus absorption by the plant. Keeping above things in consideration, an experiment was conducted in mulched groundnut with application of phosphorus to study the growth, yield, economics and weed dynamics in groundnut.

Materials and Methods

Experimental site

The field experiment was conducted at Post Graduate Research farm, M.S. Swaminathan School of Agriculture, Gajapati, Odisha (18^0 48'16" N latitude, 84^{0}10'48" E longitude and at 64 m altitude above mean sea level) during the summer season of 2022 (Fig. 1). Groundnut was sown in February 2022 and harvested in May 2022. During that crop growth period, meteorological data was recorded and presented in Fig. 2. Soil of the experimental field was sandy clay loam in texture with slightly acidic pH (6.2) and low organic carbon (0.48%). Available nitrogen, phosphorus and potassium in soil were

Fig. 1. Overview of experimental plot.

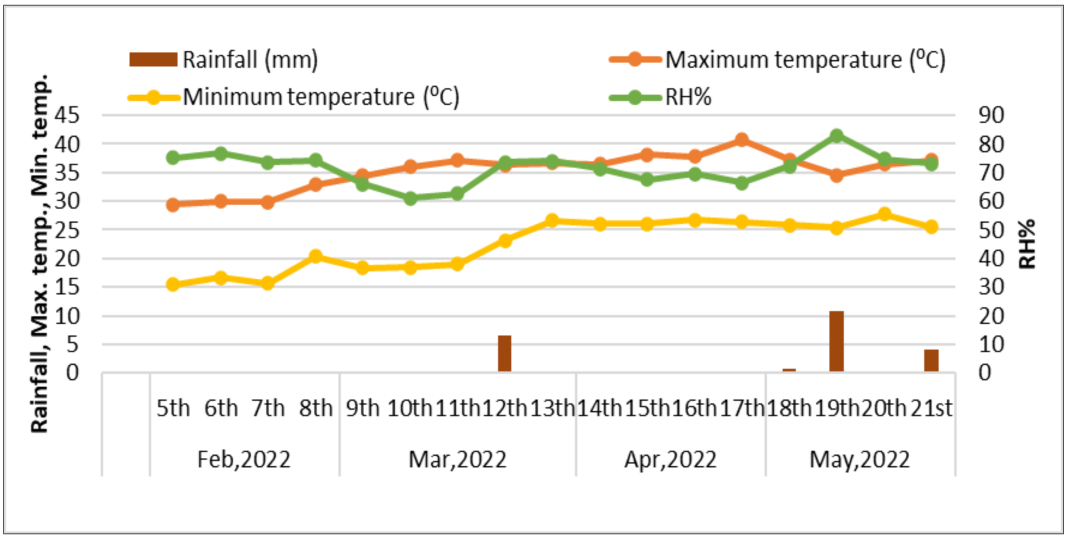

Fig. 2. Graph of weather parameters recorded during crop growing period.

175, 16.03 and 134.5 kg ha^{-1} respectively.

Experimental design and treatment details

The field experiment was laid out in Split Plot Design (SPD) with three levels of paddy straw mulching (M_1- No mulch; M_2- paddy straw mulch at 2.5 t ha^{-1} and M_3- paddy straw mulch at 5 t ha^{-1}) in main plot and 4 levels of phosphorus (P_1- P_2O_5 at 0 kg ha^{-1}; P_2 - P_2O_5 at 20 kg ha^{-1}; P_3 - P_2O_5 at 40 kg ha^{-1} and P_4- P_2O_5 at 60 kg ha^{-1}) were taken in subplots. There was a total of 12 treatment combinations and each treatment was replicated thrice. Phosphorus was applied as a single basal dose according to the treatment details. Groundnut variety Kadiri-6 (K-6) was sown in 30 x 10 cm spacing with a seed rate of 120 kg ha^{-1}. All the recommended agronomic practices were used for the successful cultivation of the crop. The recommended fertilizer dose of 20 kg N and 40 kg K_2O per ha applied to each plot.

Observations Recorded

Among the growth parameters, dry matter accumulation by the plant was recorded and from the same data, the crop growth rate was computed. At the time of harvesting, pod, kernel and haulm yield were recorded from the net plot area and it was converted to a hectare basis. Observations on total weed density as well as dry matter were taken following quadrat method. Economics was calculated based on the package of practice and on the yield attained.

Statistical analyses

The data were statistically analyzed using the ANOVA in MS Excel 2010 and the difference between the treatment means was tested for its statistical significance considering appropriate CD (critical difference) values at 5% level of significance (21).

Results and Discussion

Growth parameter

Plant dry matter accumulation

Plant dry matter accumulation was significantly influenced by both paddy straw mulching as well as levels of phosphorus at all the stages of crop growth (Table 1). At 30 DAS, application of paddy straw mulch at 5 t ha^{-1} recorded the significantly highest plant dry matter accumulation (59.4 g m^{-2}) compared to paddy straw mulch at 2.5 t ha^{-1} (47 g m^{-2}), which remained at par with no mulch (43.6 g m^{-2}). However, at 60 DAS, 90 DAS and at harvest, the treatment of paddy straw mulching at 5 t ha^{-1} recorded the highest plant dry matter accumulation (326.4, 507.3 and 647 g m^{-2} respectively) which was statistically at par with paddy straw mulching at 2.5 t ha^{-1} (307.2, 475.1 and 609.0 g m^{-2} respectively) and the significantly lowest dry matter was obtained from no mulch (246.2, 416.8 and 528.2 g m^{-2} respectively).

This result might be ascribed to the fact that where the crop competed successfully with the weeds for better sunlight and nutrients led to enhanced photosynthetic activity, increasing the plant dry matter accumulation. Similar result was reported by (22, 23). The level of phosphorus showed a significant effect on plant dry matter accumulation at all growth stages. At 30, 60, 90 DAS and at harvest, the highest dry matter accumulation was recorded in P_2O_5 at 60 kg ha^{-1} (58.2, 336.0, 521.5 and 669.3 g m^{-2} respectively), which was statistically at par with P_2O_5 at 40 kg ha^{-1} and the lowest dry matter accumulation was recorded in no mulch. The increase in dry matter in 60 kg P2O5 ha^{-1} was mostly caused by an improvement in the plant's number of primary and secondary branches as well as its leaf area index.

Earlier similar findings were reported (24). *P*hosphorus is well known to enhance the growth of vigorous root systems, which allow plants to extract more water and nutrients from deeper layers of the soil. The increment in dry weight caused by phosphorus application might be attributed to this effect. This might then improve the capacity of plants to accumulate more assimilates, which would help in increased biomass production (25). The interaction between paddy straw mulching and levels of phosphorus showed a non-significant effect on plant dry matter accumulation at all growth stages.

Crop growth rate (CGR)

Crop growth rate was significantly influenced by paddy straw mulching as well as levels of phosphorus application (Fig. 3). The CGR was higher during 30-60 DAS and decreased during further stages. During 30-60 DAS, 60-90 DAS and 90 DAS harvest, the highest CGR was recorded from the treatment of paddy straw mulching at 5 t ha^{-1}, which was statistically at par with paddy straw mulching at 2.5 t ha^{-1} and the lowest CGR was recorded from no mulch. Among phosphorus levels, the highest CGR was recorded in P_2O_5 at 60 kg ha^{-1} which was statistically at par with P_2O_5 at 40 kg ha^{-1} and the lowest CGR was recorded in no mulch.

The application of paddy straw mulch at a higher rate reduced weed growth and promoted plant growth. This also improves soil moisture availability by reducing evaporation

Table 1. Effect of paddy straw mulching and phosphorus on dry matter accumulation of summer groundnut

Treatment	Dry matter accumulation (g m^{-2})			
	30 DAS	60 DAS	90 DAS	Harvest
Paddy straw mulching (t ha^{-1})				
0	43.6	246.2	416.8	528.2
2.5	46.7	307.2	475.1	609.0
5	59.4	326.4	507.3	647.4
S. Em. (±)	1.2	11.4	14.5	16.5
CD at 5 %	4.7	44.8	56.9	64.9
Levels of phosphorus (kg ha^{-1})				
0	42.0	242.8	395.3	509.0
20	48.0	280.4	452.7	574.6
40	51.4	314.0	496.1	626.6
60	58.2	336.0	521.5	669.3
S. Em. (±)	2.2	15.1	17.4	20.2
CD at 5 %	6.6	44.8	51.6	60.0
M X P				
S. Em. (±)	3.9	26.1	30.1	35.0
CD at 5 %	NS	NS	NS	NS

loss of water and this could be the reason for the above results recorded (26). As compared to no mulch straw mulched groundnut plants were taller and branches are more vigorous due to better soil texture and microbial activity (27).

Weed growth

Total weed density (No.m^{-2})

At 30 DAS, the total weed density per m^2 was significantly influenced by both paddy straw mulching and levels of phosphorus (Table 2). The significantly lowest weed density per m^2 was recorded from paddy straw mulching at 5 t ha^{-1} (8.4) compared to paddy straw mulch at 2.5 t ha^{-1} (11.2). The lowest total weed density per m^2 was recorded in P_2O_5 at 60 kg ha^{-1} (9.9), which was at par with P_2O_5 at 40 kg ha^{-1} (10.7) and the significantly highest total weed density per m^2 was recorded in no phosphorus application. The interaction between paddy straw mulching and the level of phosphorus showed a non-significant effect on total weed density.

This might be due to poor weed seed germination because of lesser interception of incident solar radiation. Reduction in photosynthesis and metabolic activity might be the reason for the lower number of weeds in mulched treatments (28, 29). Better plant growth in treatment P_2O_5 at 60 kg ha^{-1} reduced space availability for weed growth, which in turn decreased the weed density.

Total weed dry weight (g m^{-2})

At 30 DAS, the total weed dry matter was significantly influenced by both paddy straw mulching and levels of phosphorus (Table 2). The significantly lowest weed dry matter was recorded from paddy straw mulching at 5 t ha^{-1} (6.28 g m^{-2}) compared to paddy straw mulch at 2.5 t ha^{-1} (7.51 g m^{-2}). The lowest total weed density was recorded in P_2O_5 at 60 kg ha^{-1} (7.06 g m^{-2}), which was at par with P_2O_5 at 40 kg ha^{-1} (7.34 g m^{-2}) and the significantly highest total weed density was recorded in no phosphorus application. The interaction between paddy straw mulching and the level of phosphorus showed a non-significant effect on total weed dry weight.

Low weed density also results in low weed dry weight. Paddy straw mulch reduced the solar energy flux by increasing albedo, which resulted in lower weed seed germination and weed dry weight (30). Higher phosphorus doses applied to the soil make more phosphorus availability to plants, which promoted plant growth by inhibiting weed growth. This could be the cause of the lowest weed dry weight measured from the P_2O_5 at 60 kg ha^{-1} treatment.

Yield

Pod yield (kg ha^{-1})

Pod yield was significantly influenced by both paddy straw mulching and levels of phosphorus (Fig. 4). The significantly highest pod yield was recorded from the treatment with paddy straw mulching at 5t ha^{-1} (2376 kg ha^{-1}) which was 14.72 % higher than that of no mulch (2071 kg ha^{-1}). The highest pod yield was obtained from the treatment of P_2O_5 at 60 kg ha^{-1} (2447 kg ha^{-1}) which was statistically at par P_2O_5 at 40 kg ha^{-1}

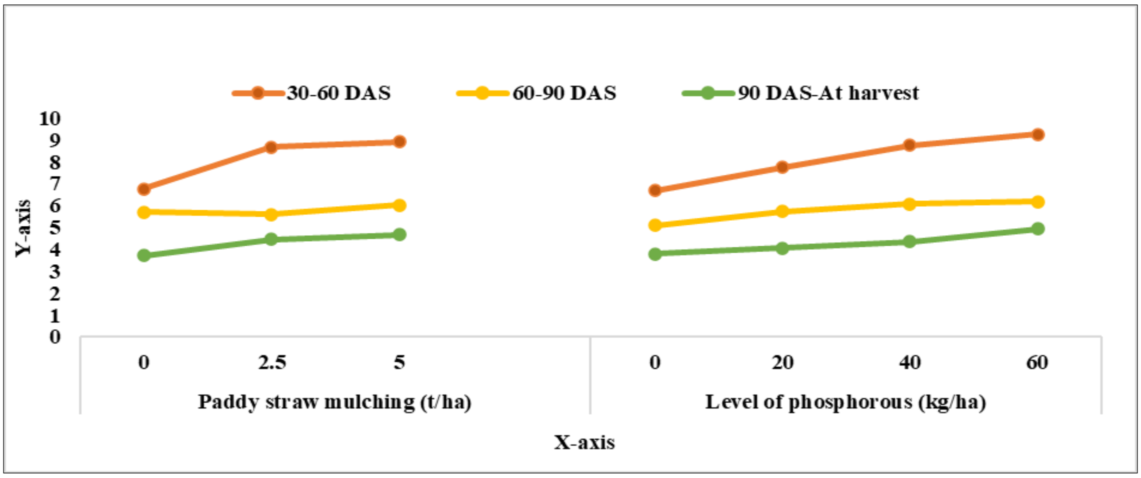

Fig. 3. Effect of paddy straw mulching and phosphorus on crop growth rate of summer groundnut.

Table 2. Effect of paddy straw mulching and phosphorus on total weed density (No.m^{-2}), total weed dry weight and soil moisture content of summer groundnut:

Treatment	Total weed density (No.m^{-2})	Total weed dry weight (g m^{-2})
	Paddy straw mulching (t ha-1)	
0	12.8(164.7)	8.58(73.27)
2.5	11.2(125.3)	7.51(56.23)
5	8.4(70.3)	6.28(39.07)
S. Em. (±)	0.1	0.11
CD at 5 %	0.38	0.44
	Levels of phosphorus (kg ha-1)	
0	11.6(137.3)	7.88(62.76)
20	11.1(126.2)	7.56(57.51)
40	10.7(116.4)	7.34(54.18)
60	9.9(100.4)	7.06(50.31)
S. Em. (±)	0.20	0.10
CD at 5 %	0.6	0.29
	M X P	
S. Em. (±)	0.4	0.17
CD at 5 %	NS	NS

*Original values are given in parenthesis, which were transformed to √x + 0.5.

(2201 kg ha^{-1}). Application of P_2O_5 at 60 kg ha^{-1} recorded 26.39 % higher yield compared to no phosphorus application. The interaction effect of paddy straw mulching and levels of phosphorus showed a non-significant effect on pod yield.

Mulching has the potential to increase production by maintaining soil moisture and temperature, which improved yield attributes and ultimately, increased the pod yield (23). The findings of the investigation strongly concluded that phosphorus have a significant impact on the production of the pod and haulm. Application of higher doses of phosphorus near rhizosphere made the plant system to have a more nutrient-richer environment; the metabolism and photosynthetic activity of the plants are increased (31). The increase in yield may be directly related to consequences of increased in plant growth and yield attributes.

Kernel yield (kg ha^{-1})

Kernel yield was significantly influenced by both paddy straw mulching and levels of phosphorus (Fig. 4). The significantly highest kernel yield was recorded from the treatment with paddy straw mulching at 5t ha^{-1} (1726 kg ha^{-1}) which was 22.32 % higher than that of no mulch (1411 kg ha^{-1}). The highest kernel yield was obtained from the treatment of P_2O_5 at 60 kg ha^{-1} (1736 kg ha^{-1}) which was statistically at par P_2O_5 at 40 kg ha^{-1} (1656 kg ha^{-1}). Application of P_2O_5 at 60 kg ha^{-1} recorded 35.49 % higher yield compared to no phosphorus application. The interaction effect of paddy straw mulching and levels of phosphorus showed a non-significant effect on kernel yield.

Higher pod yield and number of kernels per pod from mulching@ 5 t ha^{-1} and P_2O_5@ 60 kg ha^{-1} ultimately resulted higher kernel yield.

Increased in kernel yield with the rate of phosphorus application might be due to higher photosynthesis, respiration, storage and transfer of energy, cell division and elongation [32].

Haulm yield (kg ha^{-1})

Haulm yield was significantly influenced by both paddy straw mulching and levels of phosphorus (Fig. 4). The significantly highest haulm yield was recorded from the treatment with paddy straw mulching at 5t ha^{-1} (4111 kg ha^{-1}), which was at par with paddy straw mulching at 2.5t ha^{-1} of no mulch (3885 kg ha^{-1}) and the significantly lowest haulm yield was recorded in no mulch treatment (3277 kg ha^{-1}). The highest haulm yield was obtained from the treatment of P_2O_5 at 60 kg ha^{-1} (4272 kg ha^{-1}) which was statistically at par P_2O_5 at 40 kg ha^{-1} (3920 kg ha^{-1}). The lowest haulm yield was recorded with no phosphorus application (3215 kg ha^{-1}). The interaction effect of paddy straw mulching and levels of phosphorus showed a non-significant effect on kernel yield.

Mulching with paddy straw @ 5 t ha^{-1} improved microbial activity, maintained soil moisture and temperature, which provided congenial environment for higher plant height, number of branches, dry matter accumulation and leaf area. This ultimately recorded highest haulm yield. Similar results were also noticed where haulm yield under mulched conditions was much higher than under un-mulched conditions (33). The levels of phosphorus showed a significant effect on haulm yield. The addition of phosphorus to the soil may have enhanced plant metabolism, resulting in higher growth and yield. Phosphorus is also an important nutrient in groundnut production whose deficiency cause reduction in crop yield (34).

Economics

Total cost of cultivation, gross return and net return of summer groundnut as affected by paddy straw mulching (Fig. 5). The treatment combination of paddy straw mulching at 5 t ha^{-1} along with P_2O_5 at 60 kg ha^{-1} recorded the highest cost of cultivation (Rs. 45713 ha^{-1}), gross return (Rs. 145174 ha^{-1}) and net return (Rs. 99461 ha^{-1}) and the lowest cost of cultivation (Rs. 39013 ha^{-1}), gross return (Rs. 95583 ha^{-1}) and net return (Rs. 56570 ha^{-1}) were recorded from no mulch with P_2O_5 at 0 kg ha^{-1}. Mulching at 5 t ha^{-1} is more economically beneficial than 2.5 t ha^{-1} because it results in improved yield by which one can recover the increased cost of production. The cost of cultivation, net returns and benefit: cost ratio showed increasing trends with the rate of phosphorus application, although the highest net returns and benefit: cost ratio was noticed with 27 kg P ha^{-1} (25).

Conclusion

From the current study, it is concluded that paddy straw mulch at 5 t ha^{-1} smothered the weeds more effectively and recorded significantly the lowest total weed density per m^2 (8.4) and weed dry weight (6.28 g m^{-2}) which was 36.62 % and 52.38 % lesser compared to no mulch treatment. Maximum pod (2376 kg ha^{-1}) and kernel yield (1726 kg ha^{-1}) of groundnut were recorded from paddy straw mulch at 5 t ha^{-1} which were

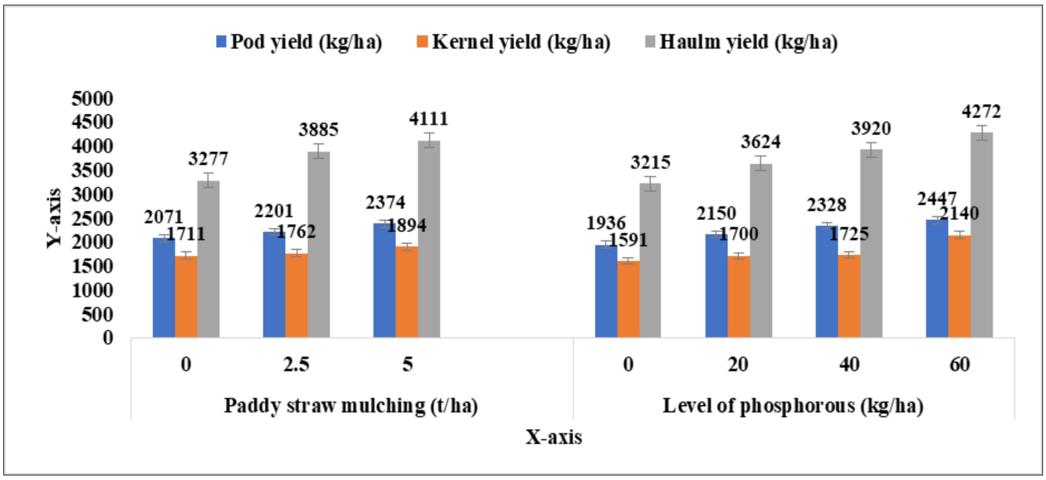

Fig. 4. Effect of paddy straw mulching and phosphorus on pod yield, kernel yield and haulm yield of summer groundnut.

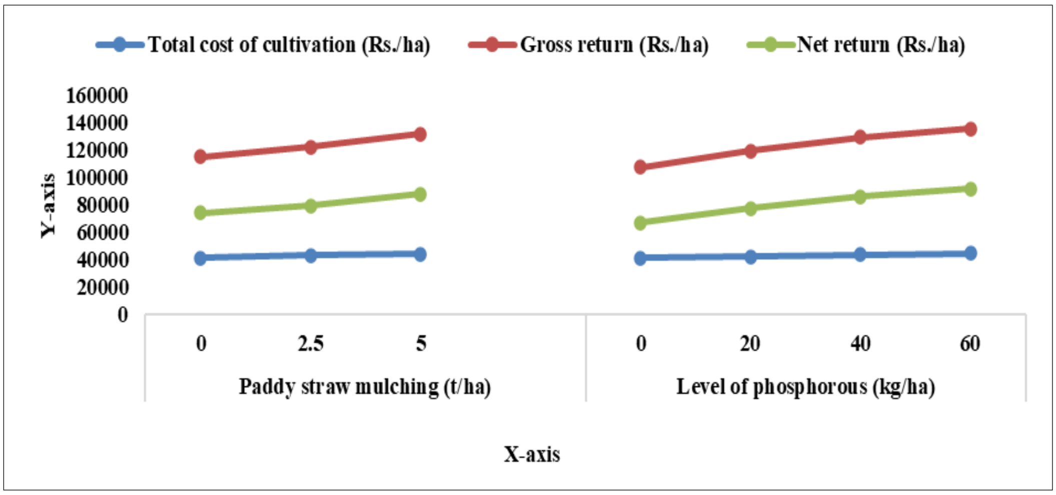

Fig. 5. Effect of paddy straw mulching and phosphorus on economics of summer groundnut.

14.72 % and 22.32 % higher than no mulch treatment. Among the levels of phosphorus, 60 kg P_2O_5 ha^{-1} recorded significantly higher pod (2447 kg ha^{-1}) and kernel yield (1936 kg ha^{-1}) which were 26.39 % and 35.41 % higher than no phosphorus application. Application of 60 kg P_2O_5 ha^{-1} also recorded the lowest weed density and dry weight which were 17.17 % and 11.61 % lesser than no phosphorus application. Application of 5 t ha^{-1} paddy straw mulch and 60 kg P_2O_5 ha^{-1} was found as the best treatment combination increasing pod and kernel yield of groundnut, decreasing weed density as well as weed dry matter and resulting in maximum gross and net return. Now a days, sustainability in agriculture is emphasized and these findings can be explored for other leguminous crops at multi locations.

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Authors' contributions

STD and JBP carried out the field experiment and statistical analysis, SN contributed in manuscript making and AM and DG helped in editing of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest

Ethical issues: None

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