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RESEARCH ARTICLE

Effect of weed management practices and fertility levels on growth, nutrient uptake and yield of groundnut (*Arachis hypogaea* L.)

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Abstract

Arachis hypogaea is an energy-dense oilseed crop yet cultivated on low-fertility soils. Among the several constraints, weed infestation and improper nutrient management are the most widespread and essential for its low productivity. A field experiment was carried out in 2020 and 2021, using four levels of fertility and four methods for controlling weeds, resulting in sixteen different treatment combinations tested three times in a factorial randomized complete block design. The weed control techniques included W_1- Pendimethalin application at 0.75 kg per hectare as a Pre-emergence (PE), W_2- Pretilachlor application at 0.5 kg per hectare as a Pre-emergence (PE), W_3-Manual weeding (20 and 40 days after sowing: DAS), W_4-Twin wheel hoe at 20 days after sowing followed by (*fb*) hand weeding at 40 days after sowing and four fertility levels includes T_1-100 % recommended dose of fertilizer (N:20::P_2O_5:40::K_2O:40), T_2- 75 % RDF + 5 FYM t ha^{-1}, T_3- 50 % RDF + 10 FYM t ha^{-1}, T_4- control. Amongst the weed control methods, the use of twin wheel hoe at 20 days after sowing *fb* hand weeding at 40 days after sowing reported the highest dry matter accumulation per plant (35.5 g), Crop growth rate (20.4 g m^{-2} day^{-1}), nutrient uptake by crop (191.9 kg ha^{-1}), NUE, agronomic use efficiency, yield and benefit-cost ratio. Among the different fertility levels, the highest dry matter accumulation per plant (39.7 g), crop growth rate (22.8 g m^{-2} day^{-1}), nutrient uptake by crop (202.4 kg ha^{-1}), pod yield and haulm yield. As a result, weeds like *Echinochloa colonum, Elusine indica, Digitaria ciliaris, Dactylotenium aegyptium, Celosia argentea, Cyperus rotundus, Borreria hispida, Cleome viscosa, Croton sparsiflorus, Phyllanthus niruri* and *Physalis minima* were effectively prevented from growing by using a twin wheel hoe at 20 DAS and manual weeding at 40 DAS. This improved the growing conditions for crops. The maximum net return and cost-benefit ratio were achieved with 50 % RDF + 10 FYM t ha^{-1} application.

Keywords: groundnut; nutrient uptake; NUE; productivity; profitability

Introduction

Groundnut, also known as the "unpredictable legume," is an herbaceous annual plant with an indeterminate growth habit. The demand for edible oils is increasing steadily, while the cultivation and yield of groundnuts have experienced a substantial decline (1). Among the several constraints, improper nutrient management and weed infestation are considerable challenges contributing to low productivity. Hence, focused efforts are being made to stabilize the production. Weed management in groundnuts can be essential in boosting crop yield, enhancing quality and increasing farmers' income. This crop is known for its extensive nutrient uptake, mainly macro and micronutrients from the soil. To ensure the soil's fertility and support higher yields, it is crucial to maintain an adequate level of organic carbon in the soil. Groundnut exhibits considerable responsiveness to fertilizer application (2). Because groundnuts are legumes, they can fix atmospheric N, so they respond less to external N applications. However, it is crucial to provide phosphorus and potassium in balanced doses, as they are essential nutrients for the growth and development of the plant. An oilseed crop requires an optimum sulphur dose for oil synthesis and calcium for proper shell formation and pod filling. Despite being an energy-rich crop, groundnut is often grown in energy-scarce conditions on poor fertility soils. Using inorganic fertilizers that lack micronutrients, minimal or no use of organic manure and improper application of nutrient fertilizer can cause a deficiency in multiple nutrients, leading to poor crop yield. Intense cropping practices and improper soil fertility management have resulted in soil fertility degradation, leading to stagnation or even declining crop production and productivity (3). To increase the production of groundnuts, it is necessary to meet the crop's nutritional requirements by combining organic, inorganic and microbial fertilizers to get higher yields (4, 5). Given groundnut productivity and nutrient requirements, the present investigation was carried out to determine the most profitable and remunerative approach for raising groundnut productivity under various fertility levels and weed control techniques.

Materials and Methods

The experiment was conducted at the OUAT farm in latitude 20°15'N and longitude 85°52' E. The study location has a hot and humid environment with an average annual precipitation of 1467 mm, with 75 % of the precipitation occurring between July and September. The average maximum temperature during the January-May summer or dry season is 34.1°C. The experimental site's sandy, clayey loam soil is classified as an *Alfisol*. Soil of the experimental site was acidic in reaction (pH 4.8), low in available P (11.3 kg ha^{-1}) and moderate in available K (198.5 kg ha^{-1}), low levels in OC (0.38 %), low in accessible N (194.6 kg ha^{-1}). In both years, lime was applied @ 0.2 LR (450 kg ha^{-1}) prior to seeding.

A factorial randomized completely block design with three replications was used for the field experiment, which was carried out in both years' summer months of January through April. The field trial included 16 treatment combinations of 4 fertility levels and 4 weed control techniques. W1-Pre-emergence (PE) application of pendimethalin @ 0.75 kg ha^{-1}, W2-pre-emergence (PE) application of pretilachlor @ 0.5 kg ha^{-1}, W3-manual weeding at 20 and 40 days after sowing and W4-twin wheel hoe at 20 days after sowing followed by manual weeding at 40 days after sowing are the weed control techniques. The four fertility levels are T1-100 % of the recommended dose of fertilizer (RDF) (N: 20: P_2O_5: 40: K_2O:40 kg ha^{-1}), T2- 75 % RDF + FYM @ 5 t ha^{-1}, T3- 50 % RDF + FYM @ 10 t ha^{-1} and T4: control. The crop was treated with urea, SSP and MOP, respectively and fertilized as basal under treatment. The groundnut cultivar "ICGV91114" (Devi) was sown with the same treatments on January 6, 2020 and January 5, 2021, at 30 × 10 cm spacing.

For sowing, a seed rate of 150 kg ha^{-1} was used. To avoid seed-borne disease, the kernels were treated with the fungicide Thiram at a 2 g kg^{-1} kernel rate seven days before sowing. The day before sowing, they were treated with rhizobium at a rate of 20 gm $kernel^{-1}$. Based on the treatments, all the cultural practices related to weeding were done. One day after seeding, the first irrigation was done for uniform germination, followed by six supplementary irrigations based on groundnut requirements at different phases of the crop cycle. The crop was harvested on April 30 in 2020 and April 30 in 2021. At the appropriate time, important observations were noted.

Dry matter accumulation

Five plants were taken out from sample rows at the 30th, 60th and 90th days after seeding and harvest. The plant's roots were separated and the soil adhered to them was washed off with water. After a few days of air drying, the complete plant sample was oven-dried at 72°C until its weight remained consistent. Then the weight of the plants was taken and expressed in grams.

Crop growth rate (CGR)

The crop growth rate measures the amount of growing materials per unit of dry weight per unit of time. It is expressed in g m^{-2} day^{-1}.

$$CGR= \frac{W_2-W_1}{t_2-t_1} \qquad \text{(Eqn. 1)}$$

W_1 and W_2 are dry matter at times t_1 and t_2, respectively.

Relative growth rate (RGR)

It is the increase in dry weight over time per unit weight of the plant and is defined as the amount of dry matter produced by one gram of existing dry matter in a day.

$$RGR\ (g\ g^{-1}\ day^{-1})= \frac{\ln W_2-\ln W_1}{t_2-t_1} \qquad \text{(Eqn. 2)}$$

Where ln W_2 and ln W_1 are the natural logarithm of total dry weight of the plant at the time of t_2 and t_1, respectively.

Approaches to evaluating NUE

Apparent recovery efficiency

Crop nutrient absorption from fertilizers applied expressed as a proportion of total nutrients applied.

$$ANR\ (\%) = \frac{(NU_{\text{in fertilized plot}}-NU_{\text{in control plot}})\ (kg\ ha^{-1})}{NA\ (kg\ ha^{-1})} \times 100 \qquad \text{(Eqn. 3)}$$

Agronomic use efficiency

It is defined as the number of additional crop units produced per unit of nutrient added, expressed in kilograms of grain per kilogram of nutrient. It was computed based on the following:

$$AE = \frac{(GY_{\text{in fertilized plot}}-GY_{\text{in control plot}})\ (kg\ ha^{-1})}{NA\ (kg\ ha^{-1})} \qquad \text{(Eqn. 4)}$$

Physiological use efficiency

It was computed based upon below formula:

$$PUE= \frac{(GY_{\text{in fertilized plot}}-GY_{\text{in control plot}})\ (kg\ ha^{-1})}{(NU_{\text{in fertilized plot}}-NU_{\text{in control plot}})\ (kg\ ha^{-1})} \qquad \text{(Eqn. 5)}$$

Plant analysis for nutrient removal by groundnut and associated weed

Proper sample collection was done in order to assess the removal of N, P and K by groundnut and weed. A different polythene bag was used to store the crop's pod and haulm. The composite samples of each treatment were taken for the purpose. Samples were oven dried at 72°C for 72 h. They were put through a 2 mm screen and prepared for final grinding. Modified Micro-Kjeldahl's method, Di-acid digestion method and colorimetric measurement and Flame photometer method were used to analyze the total number of nitrogen atoms (6, 7).

Statistical analysis

A factorial randomized complete block design was used to collect, process and analyze the data (8). Prior to variance estimation analysis, all data underwent a homogeneity of error variances test. The protected least significant difference test was applied at $p \le 0.05$ to compare treatment means.

Results and Discussion

Dry matter accumulation per plant

The advancement of groundnut phenophases in 2020 and 2021 showed an increase in dry matter accumulation, as depicted in Fig. 1, which presents the pooled data. When compared to other weed control techniques, the twin wheel hoe method at 20 days and 40 days after sowing and manual weeding resulted in the maximum dry matter accumulation per plant (35.5 g) at harvest. At 20 and 40 days after sowing, it was statistically equivalent to manual weeding (33.4 g). When using Pretilachlor rate 0.5 kg per hectare (PE) to control weeds, the lowest dry matter accumulation per plant (28.1 g) was observed. Further reference to data in Fig. 1 revealed that Applying 50 % RDF + FYM 10 t ha^{-1} resulted in the maximum dry matter accumulation per plant (39.7 g) at harvest, which was significantly higher than other fertility levels. However, it remained statistically at par with application of 75 % RDF + 5FYM t ha^{-1} (37.1 g). This has been achieved by effectively managing the growth of weeds in 2020 and 2021, which improved the environment for groundnut development and growth and decreased weed competition for nutrients and moisture at the crucial stage of crop growth. Results from (9, 10) were similar.

When FYM and RDF are combined, the organic matter may improve soil health, accumulating more biomass and increasing plant dry matter production in 2020 and 2021.

The lowest dry matter accumulation per plant (17.6 g) was recorded under control. This was in confirmation with the findings of (11, 12).

Crop growth rate and relative growth rate

Strategies for managing weeds and nutrients significantly impact the groundnut crop growth rate (CGR) and relative growth rate (RGR). Fig. 2–3 show the pool data for the cropping years 2020 and 2021.The CGR increased with advancement of phenophases of crop up to 90 DAS and thereafter, it declined (Fig. 2). The RGR recorded highest value at the initial crop stages and gradually declined thereafter upto harvest (Fig. 3).

When comparing the various weed control techniques, the one with the maximum CGR (g m^{-2} day^{-1}) (20.4) was observed at 60-90 DAS. This was achieved by using a twin wheel hoe 20 days after sowing and manual weeding 40 days after sowing. With Pretilachlor rate 0.5 kg ha^{-1} (PE) used for weed control, the lowest CGR (g m^{-2} day^{-1}) (17.2) was observed. On the other hand, the lowest RGR (mg g^{-1} day^{-1}) (58.17) was recorded under weed control with twin wheel hoe at 20 day after sowing followed by manual weeding at 40 days after sowing. In contrast, the maximum RGR (mg g^{-1} day^{-1}) (69.66) was recorded at 30-60 DAS with weed management using pretilachlor rate 0.5 kg ha^{-1} (PE). It also created favourable conditions for crop growth by allowing for more prolonged weed-free environments. Research indicates similar results from their research trials (9).

Further reference to data in Fig. 1 revealed that the highest CGR (g m^{-2} day^{-1}) (22.8) was recorded at 60-90 DAS with applying 50 % RDF + 10 tons FYM ha^{-1}. The lowest CGR (g m^{-2} day^{-1}) (10.9) was recorded under control. However, the highest RGR (mg g^{-1}day^{-1}) (68.26) was reported at 30-60 DAS under control while the lowest RGR (mg g^{-1}day^{-1}) (61.14) was reported with applying of 50 % RDF + 10 tons FYM per hectare. The

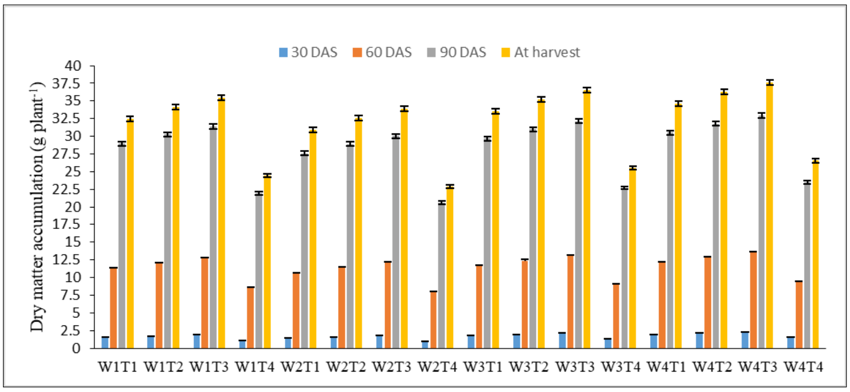

Fig. 1. Dry matter accumulation (g plant^{-1}) at different stages of groundnut crop as influenced by different weed management practices and fertility levels (Pooled data for 2020 and 2021).

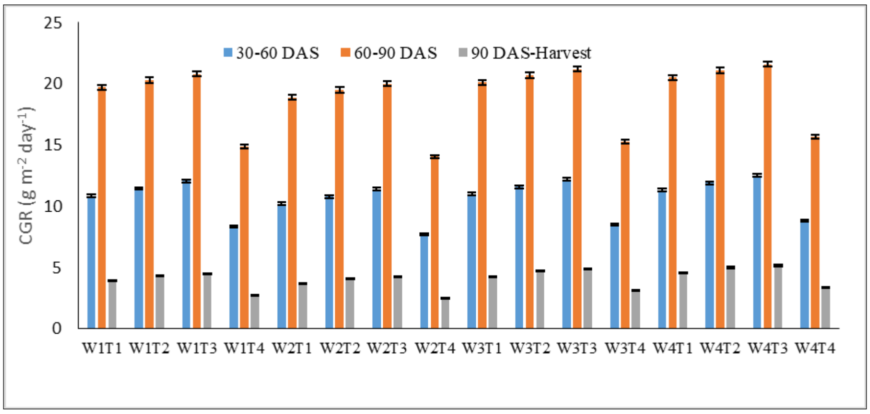

Fig. 2. CGR at different stages of groundnut crop as influenced by different weed management practices and fertility levels (Pooled data for 2020 & 2021).

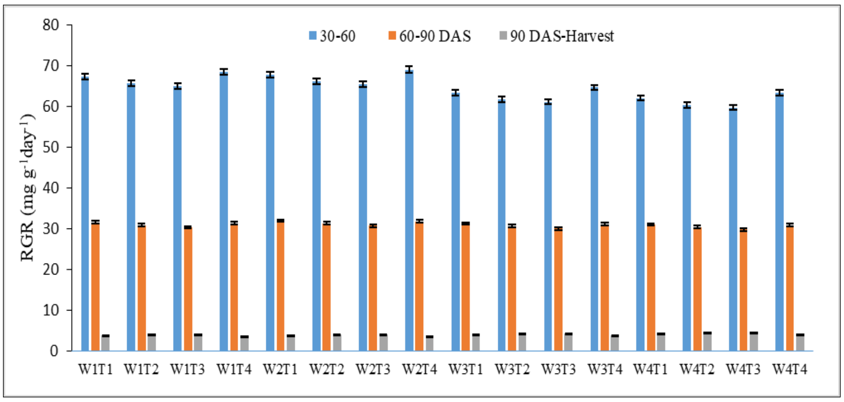

Fig. 3. RGR at different stages of groundnut crop as influenced by different weed management practices and fertility levels (Pooled data for 2020 & 2021).

presence of relatively higher amounts of readily available essential nutrients, plant growth regulators, hormones, root exudates, beneficial organisms, antibiotics, vitamins and hormones could explain the beneficial effects of FYM (Farmyard Manure) on plant growth. Thus, nutrients had a positive influence on vegetative growth and, as a result, had a positive influence on the crop. Research indicates the similar results from their research trials (13, 14).

Nutrient uptake

Nutrient uptake by crop

Nutrient uptake is a key factor for strategic nutrient management to achieve potential yield of crop. Nutrient uptake of groundnut was significantly influenced by weed and nutrient management practice during the field trail and the pooled data of 2020 and 2021 are shown in Table 1. It was found that, of the different weed control techniques, the use of a twin wheel hoe at 20 days after sowing and hand weeding at 40 days after sowing resulted in the maximum crop nutrient uptake (191.9 kg ha^{-1}), while the use of pretilachlor rate 0.5 kg per hectare (PE) produced the lowest nutrient uptake by crop (137.7 kg ha^{-1}). Due to efficient weed management, more nutrients could be absorbed from the soil and the crop. Research indicates the similar results from their research trials (15).

Among the different fertility levels, the highest nutrient uptake by crop (202.4 kg ha^{-1}) was recorded with 50 % RDF + 10 tons FYM ha^{-1}. In contrast, the lowest nutrient uptake by crop (94.9 kg ha^{-1}) was recorded under the control (without fertilizer + without FYM). This was due to the plant access of nutrients in readily available form throughout the growth period and higher dry matter accumulations resulting in an increased uptake. Research indicates the similar results from their research trials (16, 17, 18).

Nutrient removal by weeds

The pooled data on nutrient uptake by weeds during 2020 and 2021 are presented in Table 1. It revealed that among various weed management practices, the lowest nutrient removal by weeds (24.6 kg ha^{-1}) was recorded with use of twin wheel hoe at 20 days after sowing and subsequently hand weeding at 40 DAS, while the highest nutrient removal by weeds (66.0 kg ha^{-1}) was recorded under weed management with pretilachlor @ 0.5 kg ha^{-1} (PE) application. It is anticipated that weed interference will be reduced through timely, spatially targeted and efficient control of weeds such as *Digitaria ciliaris*, *Dactylotenium aegyptium*, *Eleusine indica*, *Echinochloa colonum*, *Cyperus rotundus*, *Borreria hispida*, *Celosia argentea*, *Croton sparsiflorus*, *Cleome viscosa*, *Phyllanthus niruri* and *Physalis minima*, as well as by creating a better environment for crop growth. The findings are consistent with those of (19, 20).

Among the different fertility levels, the lowest nutrient removal by weeds (11.58 kg ha^{-1}) was recorded under the control plot. Meanwhile, the highest nutrient removal by weed (27.0 kg ha^{-1}) was recorded under 100 % RDF. Due to the free environment at the initial stages, a judicious combination of inorganic and organic fertilizers increased the nutrient concentration in the soil solution and their plant uptake. Chemical fertilizers increase weed density and make nutrients more readily available to weeds than to crops. This could help in higher nutrient removal in inorganic fertilization plots

Table 1. Total nutrient uptake (kg ha^{-1}) by crop and total nutrient removal by weeds (Pooled data for 2020 and 2021) as influenced by different weed management practices and fertility levels

Treatments	Nutrient uptake by crop (kg ha^{-1})				Nutrient removal by weeds (kg ha^{-1})			
	N	P	K	Total N P K uptake	N	P	K	Total N P K removal
Weed management practices								
W_1: Pendimethalin @ 0.75 kg ha^{-1} (PE)	80.2	8.2	52.0	140.4	26.8	9.7	22.9	59.4
W_2: Pretilachlor @ 0.5 kg ha^{-1} (PE)	78.5	7.9	51.3	137.7	30.1	10.5	25.4	66.0
W_3: Manual weeding (20 and 40 DAS)	104.0	10.9	68.0	182.9	13.8	5.5	10.9	30.2
W_4: Twin wheel hoe at 20 DAS followed by hand weeding at 40 DAS	109.1	11.6	71.2	191.9	10.7	4.8	9.1	24.6
SEm±	3.68	0.51	3.21	6.41	1.47	0.21	1.62	1.52
CD (P=0.05)	12.4	2.41	8.46	20.3	6.91	0.93	3.24	4.21
Fertility levels								
T_1:100 % RDF	90.7	9.3	59.3	159.3	11.7	6.0	9.3	27.0
T_2: 75 % RDF + 5 tonnes FYM ha^{-1}	112.5	11.0	72.8	196.3	9.5	3.9	7.5	20.9
T_3: 50 % RDF + 10 tonnes FYM ha^{-1}	115.4	12.6	74.4	202.4	7.4	3.4	5.6	16.4
T_4: Without fertilizer + without FYM	53.2	5.7	36.0	94.9	5.28	1.72	4.58	11.6
SEm±	2.11	0.61	3.24	5.71	0.82	0.26	1.24	2.46
CD (p=0.05)	9.43	1.82	12.6	14.6	1.24	3.12	2.34	5.21

compared to integrated nutrient management plots. Research indicates the similar results from their research trials (21, 22).

Nutrient use efficiency

Apparent recovery efficiency

The absolute effectiveness of externally applied fertilizer for crop growth is calculated using apparent recovery efficiency. Nutrient and weed management in groundnut had a significant effect on the pooled data on apparent recovery efficiency in 2020 and 2021 (Table 2 and Fig. 4). The results of this study indicated that, of the different weed control techniques, the use of a twin wheel hoe at 20 DAS subsequently 40 DAS hand weeding at produced the highest apparent recovery efficiency for N, P and K (1.86, 0.18 and 1.17), while the use of pretilachlor rate 0.5 kg ha^{-1} (PE) produced the lowest apparent recovery efficiency for N, P and K (0.84, 0.07 and 0.51). This can be explained by hand weeding after hoeing, which improves weed control during the most critical stage of crop-weed competition and enhances nutrient use efficiency. Research indicates the similar results from their research trials (20, 22).The highest apparent recovery efficiency for N and K (1.88 and 1.17) was recorded in 100 % RDF among the different fertility levels. In comparison, the P use efficiency (0.15) was reported to be highest in 50 % RDF + 10 FYM t ha^{-1} application. This might be due to applying fertilizers through organic and inorganic combinations, supplying the essential nutrients in adequate quantity and allowing maximum plant uptake throughout the crop growth period. The results were in line with the findings of (23).

Significant results were obtained for the interaction effect (Fig. 4). Twin wheel hoe weed management at 20 DAS, subsequently 40 DAS hand weeding and 100 % RDF produced the highest apparent recovery efficiency for N and K (1.87 and 1.17). In comparison, the P use efficiency (0.165) was the highest under Twin wheel hoe weed management at 20 DAS and subsequently, 40 DAS hand weeding and application of 50 % RDF + FYM 10 t ha^{-1}.

Agronomic use efficiency

Agronomic efficiency, which contributes to yield sustainability, measures the quantity of dry matter produced per unit supply of nutrients. Table 2 and Fig. 5 provide the combined data on agronomic use efficiency for 2020 and 2021. The data analysis revealed that among the different weed control techniques, by using twin wheel hoe at 20 days after sowing subsequently manual hand weeding at 40 days after sowing had the highest agronomic use efficiency for primary nutrient (N, P and K) (32.1, 30.2 and 32.1), while the use of pretilachlor rate 0.5 kg per hectare (PE) had the lowest agronomic use efficiency for N, P and K (12.5, 11.8 and 12.5) (Table 2). Maintaining a weed-free environment helps the crop plant get nutrients, maximizes the number of mature pods per plant and increases the pod yield per hectare. Research indicates similar results from their

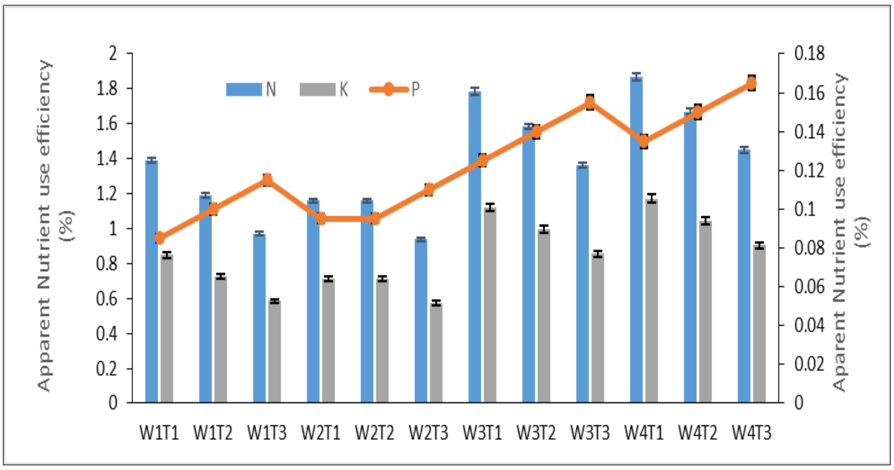

Fig. 4. Apparent nutrient use efficiency of groundnut as influenced by different weed management practices and fertility levels (Pooled data for 2020 & 2021).

Table 2. Nutrient use efficiency, agronomic use efficiency and production efficiency of groundnut as influenced by different weed management practices and fertility levels (Pooled data for 2020 and 2021)

Treatments	Nutrient use efficiency (%)			Agronomic use efficiency (kg kg^{-1})			Production efficiency (kg kg^{-1})		
	N	P	K	N	P	K	N	P	K
Weed management practices									
W_1: Pendimethalin @ 0.75 kg ha^{-1} (PE)	0.90	0.08	0.53	15.0	14.1	15.0	16.7	180.0	28.1
W_2: Pretilachlor @ 0.5 kg ha^{-1} (PE)	0.84	0.07	0.51	12.5	11.8	12.5	14.9	170.9	24.6
W_3: Manual weeding (20 and 40 DAS)	1.69	0.16	1.07	28.6	26.9	28.6	16.9	165.2	26.8
W_4: Twin wheel hoe at 20 DAS followed by hand weeding at 40 DAS	1.86	0.18	1.17	32.1	30.2	32.1	17.2	163.2	27.4
SEm±	0.11	0.01	0.11	1.10	0.46	1.24	0.26	2.46	0.21
CD (P=0.05)	0.53	0.05	0.41	7.81	6.42	5.12	1.32	8.41	1.21
Fertility levels									
T_1: 100 % RDF	1.88	0.09	1.17	31	15.5	31.0	16.5	172.0	26.6
T_2: 75 % RDF + 5 tonnes FYM ha^{-1}	1.48	0.12	0.92	23.9	22.5	23.9	16.1	180.2	26.0
T_3: 50 % RDF + 10 tonnes FYM ha^{-1}	1.04	0.15	0.64	17.9	23.9	17.9	17.3	155.7	28.0
SEm±	0.16	0.02	0.03	2.41	1.06	1.54	0.82	2.14	0.23
CD (p=0.05)	0.51	0.11	0.31	6.21	3.21	7.21	3.21	12.71	2.12

research trials. The highest agronomic use efficiency for N and K (31 and 31.0) was recorded with 100 % RDF among the different fertility levels. In comparison, agronomic P use efficiency (23.9) was reported to be highest with the application of 50 % RDF + 10 tons FYM per hectare. This might be due to higher nutrient content, which would be responsible for increased uptake of nutrients by the crop and sustaining higher yield. Research indicates the similar results from their research trials (26, 27). The twin wheel hoe weed management at 20 days after sowing followed by hand weeding at 40 days after sowing and application of 100 % RDF produced the highest agronomic use efficiency for N and K among the treatment combinations, while the twin wheel hoe weed management at 20 DAS followed by manual weeding at 40 days after sowing with 50 % RDF + FYM @ 10 t ha^{-1} application produced the highest P use efficiency (27.05) (Fig. 5).

Physiological use efficiency

Table 2 and Fig. 6 display the 2020 and 2021 pool data. Among the different weed management techniques, it was noticed that applying Pendimethalin rate 0.75 kg ha^{-1} (PE) had the highest physiological use efficiency for P and K (180.0 and 28.1 kg pod kg^{-1} nutrient applied), while the use of twin wheel hoes at 20 days after sowing and hand weeding at 40 DAS had the highest physiological use efficiency for N (17.2). Effective weeding techniques, like manual hand weeding and hoeing, reduce weed interference and increase crop growth efficiency in the early stages. Research indicates the similar results from their research trials (28). Among the various fertility levels, 50 % RDF + 10 tons of farm yard manure per hectare had the highest physiological efficiency for N (17.3) and K (28.0). In comparison, 75 % RDF + 5 tons FYM ha^{-1} was found to have the highest physiological efficiency for P (180.2). This could be because more nutrients are available, promoting higher nutrient uptake and, ultimately, higher production. Research indicates the similar results from their research trials (29, 30). The highest physiological efficiency for N (17.25) and K (27.2 %) was achieved by twin wheel hoeing 20 days after sowing and manual weeding 40 days after sowing with 50 % RDF + 10 tons FYM per hectare. Applying Pendimethalin @ 0.75 kg ha^{-1} (PE) in conjunction with 75 % RDF + 5 tons FYM per hectare resulted in the highest physiological efficiency for P (Fig. 6). Physiological efficiency was calculated as the yield per unit of food intake increased compared to the control plot.

Groundnut yield attributes and yield

Out of all the weed control methods evaluated, data in Table 3 demonstrated that the maximum pod yield (1.78 t ha^{-1}) and haulm yield (3.40 t ha^{-1}) were recorded using a twin wheel hoe 20 DAS and subsequently hand manual weeding 40 DAS. This may be because the crop does not have to compete with weeds during the crucial time for light, nutrients, moisture and space, which improves growth conditions and allows the crop to reach its maximum yield potential. The outcomes are consistent with the results of (31). The haulm yield (3.53 t ha^{-1}) and pod yield (1.89 t ha^{-1}) were greatly enhanced by applying 50 % RDF + 10 tons FYM ha^{-1} (Table 3). A general improvement in vegetative growth and nodulation may have contributed to higher values in these yield parameters by favouring flowering, fruiting and pod filling, producing more mature pods and pod-weight plant^{-1}. Research indicates similar results from their research trials (32).

Economics

The most crucial part of the analysis is the production

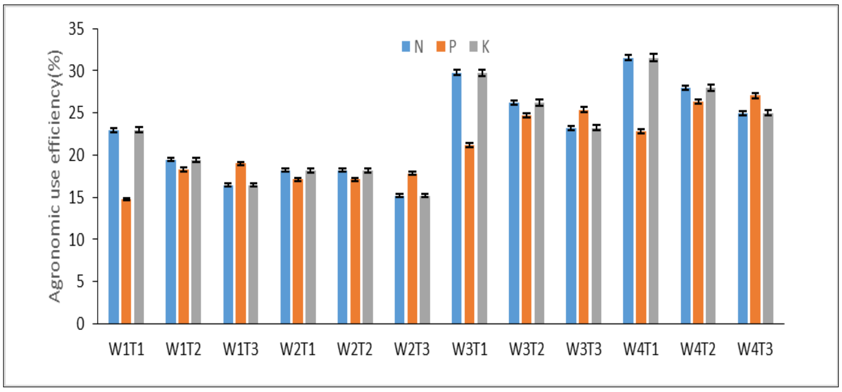

Fig. 5. Agronomic use efficiency (%) of groundnut as influenced by different weed management practices and fertility levels (Pooled data for 2020 & 2021).

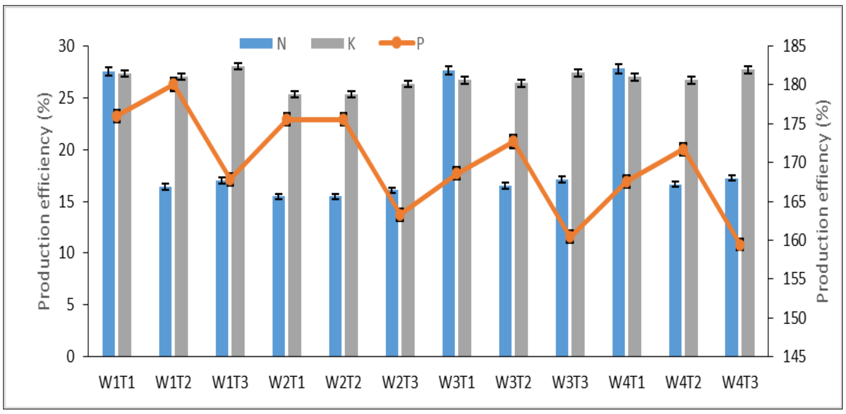

Fig. 6. Production efficiency (%) of groundnut as influenced by different weed management practices and fertility levels (Pooled data for 2020 and 2021.

Table 3. Effect of different weed management practices and fertility levels on yield and economics of groundnut (Pooled data for 2020 and 2021)

Treatments	Pod yield ($t\ ha^{-1}$)	Haulm yield ($t\ ha^{-1}$)	Cost of cultivation ($\times 10^3$ ₹ ha^{-1})	Gross return ($\times 10^3$ ₹ha^{-1})	Net return ($\times 10^3$ ₹ ha^{-1})	B:C
Weed management practices						
W_1: Pendimethalin @ 0.75 kg ha^{-1} (PE)	1.27	2.52	48.956	71.291	22.335	1.5
W_2: Pretilachlor @ 0.5 kg ha^{-1} (PE)	1.19	2.48	48.456	74.061	25.605	1.5
W_3: Manual weeding (20 and 40 DAS)	1.67	3.25	56.881	90.442	33.561	1.6
W_4: Twin wheel hoe at 20 DAS *fb* hand weeding at 40 DAS	1.78	3.40	55.381	92.588	37.207	1.7
SEm±	0.046	0.085	1.50	2.26	1.02	0.03
CD (P=0.05)	0.148	0.291	5.24	8.20	3.27	0.1
Fertility levels						
T_1: 100 % RDF	1.43	2.77	47.350	71.028	23.678	1.5
T_2: 75 % RDF + 5 tonnes FYM ha^{-1}	1.77	3.38	55.675	87.037	31.362	1.6
T_3: 50 % RDF + 10 tonnes FYM ha^{-1}	1.89	3.53	58.800	99.961	41.161	1.7
T_4: Without fertilizer + without FYM	0.82	1.99	45.130	54.156	9.026	1.3
SEm±	0.046	0.085	1.50	2.34	1.02	0.03
CD (p=0.05)	0.148	0.291	5.24	8.34	3.27	0.1

economics since, even if soil fertility is maintained and yield and gross return increase, no farmer will engage in an unprofitable practice. Therefore, the current market price was used to calculate the cost of production and return. When twin wheel hoe weed control methods were used at 20 days after sowing and hand weeding at 40 days, the maximum gross returns (92.588$\times 10^3$ ₹ha^{-1}), net returns (37.207$\times 10^3$ ₹ha^{-1}) and benefit-cost ratio (1.7) were observed (Table 3). The returns were maximum and the cultivation cost was minimal because of the increased pod production and decreased weed density. When mechanization and human weeding are combined, labour and pesticide costs are reduced and the soil-beneficial biota is improved, contributing to increased groundnut productivity (28). The highest gross returns (99.961$\times 10^3$ ₹ ha^{-1}), net returns (41.161$\times 10^3$ ₹ ha^{-1}) and benefit-cost ratio (1.7) were reported for 50 % RDF and 10 tons farm yard manure per hectare among the fertility levels. Higher shelling percentage, haulm yield and pod production could cause this. Research indicates similar results from their research trials (33, 34).

Conclusion

Groundnut weed control and fertility level experiments carried out in the 2020 and 2021 cropping years provided valuable information on strategically controlling weeds and nutrients to attain sustained farmer income and effective resource use. According to the previous pooled data analysis, twin wheel hoe weed control at 20 DAS and manual hand weeding at 40 DAS successfully inhibited weed flora and enhanced crop growing conditions. Among the different fertility levels, applying 10 T of farm yard manure per hectare and 50 % of the recommended fertilizer dose enhanced productivity and enriched the soil. Therefore, using organic nutrient sources like farm yard manure instead of some of the prescribed fertilizer dosages may be a superior way to increase profitability and improve yield quality. A field demonstration study of future farmers is necessary to disseminate technologies and guide policy choices.

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Authors' contributions

SS experimented and prepared the original draft. SJ and RD conceptualized the study and provided overall guidance for the research, while KK contributed to formal analysis and corrections. SB helped in investigation and editing. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

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