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Productivity and Econometric Analysis of Leguminous Monkey-nut (*Arachis hypogaea* L.) as Influenced by Growth Retardant

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ABSTRACT

Background: Groundnut (*Arachis hypogaea* L.) holds significant importance as a staple food legume and a key economic crop, serving as a valuable source of edible oil and protein in India. However, its full yield potential is often hampered by excessive vegetative growth, which leads to suboptimal yields. With this background, a field experiment was conducted at the Perunthalaivar Kamaraj Krishi Vigyan Kendra in Puducherry during 2020 and 2021. The objective was to investigate the influence of different concentrations and timing of paclobutrazol (PBZ) application on the growth and yield of groundnut.

Methods: The experiment was laid out in a split-plot design with three replications, six main plot treatments (Including PBZ concentrations of 25, 50, 100, 150, 200 ppm and a control) and three sub-plot treatments (Involving single sprays at 30 days after emergence (DAE), single sprays at 50 DAE and double sprays at 30 and 50 DAE).

Result: The results revealed that the application of paclobutrazol at different concentrations had a positive effect on reducing plant height during the later stages of growth, particularly when a double spray was applied at 30 and 50 DAE. Notably, the application of paclobutrazol at a concentration of 200 ppm in groundnut cultivation proved to be economically viable, resulting 29% increase in pod yield compared to the control group. Specifically, PBZ at 200 ppm, with a double spray, significantly boosted the total pod yield to 2724 kg ha^{-1}. Furthermore, the correlation and regression analyses indicated a positive relationship between growth and yield.

Key words: Economics, Groundnut, Growth parameters, Paclobutrazol, Yield components.

INTRODUCTION

India is a second-largest groundnut producer globally, trailing only behind China, holds a pivotal role in the country's agricultural landscape (APEDA, 2018). Groundnut, scientifically known as *Arachis hypogaea* L., is a self-pollinating legume known by various names such as monkeynut and peanut. It belongs to the Fabaceae family and is commonly referred to as "moongphali" in India (Hamakareem *et al*., 2016). This remarkable crop ranks among the most important oilseed crops, boasting an oil content ranging from 44% to 56% and a protein content of 22% to 30% on a dry seed basis. In India, groundnut takes the lead in both production and cultivation area, claiming approximately 45% of the total oilseed area and contributing to 55% of the total oilseed production (Lenka *et al*., 2023).

Groundnut cultivation in India spans all three primary agricultural seasons: *kharif*, *rabi* and *summer*, primarily under rainfed conditions. Among these seasons, *kharif* cultivation alone constitutes a substantial 75% share of the total groundnut production (Barman *et al*., 2017). Groundnut, characterized as a semi-determinate crop, exhibits persistent vegetative growth even after entering the reproductive stage. This prolonged vegetative phase is a key factor contributing to a sink-source imbalance, ultimately resulting in reduced yields. Furthermore, during the *kharif* season, mutual shading due to excessive vegetative growth hampers groundnut production (Gatan and Gonzales, 2015). The excessive allocation of dry matter to the stems exacerbates the crop's harvest index, posing additional challenges.

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Plant growth regulators are the chemical substances, when applied at low concentration modify the growth of plants usually by stimulating or inhibiting part of the natural growth regulatory system. About sixty plant growth regulators are now commercially available and several of them have reached considerable importance in crop production (Ajaykumar and Krishnasamy, 2019). The growth regulators include both growth promoters and retardants which modify the canopy structure and their expression in the form of yield.

The utilization of growth retardants presents an opportunity to modulate the allocation of assimilates, potentially increasing production and enhancing crop management. Paclobutrazol (PBZ), a member of the triazole family, acts by inhibiting gibberellin biosynthesis, thereby reducing shoot length and facilitating the efficient partitioning of assimilates (Ziauka and Kuusiene, 2010). The objective of this research was to investigate the effects of different concentrations of PBZ and varying application timings on plant growth, yield and economic considerations in groundnut cultivation.

MATERIALS AND METHODS

A field experiment was conducted at Perunthalaivar Kamaraj Krishi Vigyan Kendra, Puducherry during 2020 (*Kharif*) and 2021 (*Kharif*) to scrutinize the influence of various concentrations and timings of paclobutrazol (PBZ) application on the growth and yield of groundnut. The experimental layout adhered to a split-plot design, featuring six primary plots and three subplots, all replicated three times. The main plots encompassed distinct concentrations of Paclobutrazol, denoted as follows: T_1: 25 ppm, T_2: 50 ppm, T_3: 100 ppm, T_4: 150 ppm, T_5: 200 ppm and T_6: Control. The subplots, on the other hand, were devoted to exploring three distinct timings of application, designated as S_1: Single spraying at 30 DAE (Days after emergence), S_2: Single spraying at 50 DAE and S_3: Double spraying at both 30 and 50 DAE.

Groundnut variety VRIGn -6 was used for the study. Prior to sowing, the entire recommended fertilizer dose (20:50:75 kg of NPK per hectare) was evenly applied as a basal application. This dose consisted of urea, single superphosphate and muriate of potash. Gypsum, at a rate of 500 kilograms per hectare, was applied in two equal portions: one during basal application and the other during earthing up, which took place around 40 days after sowing (DAS). All other agronomic practices were meticulously executed in accordance with the specific requirements of the groundnut crop. Within each plot, ten plants were systematically chosen at random and duly tagged for the purpose of recording vital observations related to growth, yield attributes and overall yield. At the point of maturity, the crop was skillfully harvested, threshed and the resulting seed yield, measured in kilograms per hectare, was meticulously recorded. The dataset encompassing diverse parameters was subjected to thorough statistical analysis using Fisher's ANOVA method, as advocated by Gomez and Gomez (2010).

Quantitative variables analysis

Correlation analysis was employed to assess the degree of association between different variables (Ravi *et al*., 2023). Specifically, the Pearson correlation coefficient (PCC) was used to quantify the strength and direction of these relationships. The variables under consideration in this research encompassed pod yield (kg ha^{-1}), pods plant^{-1} (No.), 100 kernel weight (g), shelling (%), SMK (%), number of branches plant^{-1}, root dry weight (g) and DMP (g plant^{-1}) (Ajaykumar *et al*., 2022). The application of correlation analysis aimed to unveil the associations among these variables, shedding light on their impact on pod yield. By employing this comprehensive approach, we sought to gain deeper insights into the factors influencing pod yield. It was expressed mathematically as,

$$r_{xy} = \frac{S_{xy}}{S_x S_y} = \frac{\Sigma (x_i - \bar{x})(y_i - \bar{y})}{[\Sigma (x_i - \bar{x})^2][\Sigma (y_i - \bar{y})^2]}$$

Where,

r_{xy} = The strength of the linear association between the variables x and y.

'S_x' and 'S_y' = The sample standard deviations.

'Sxy' = The sample covariance;

'xi' and 'yi' = The respective values of the x and y variables within the sample drawn from the population.

$\bar{x}$ and $\bar{y}$ = The sample means.

Furthermore, another valuable econometric technique employed in this study was regression analysis, which rigorously examines the interrelationship between a dependent variable and a set of independent variables. This approach has been substantiated by previous research conducted by Maulud and Abdulazeez *et al*. (2020) and it was represented as:

$$Y_i = \alpha + \beta X_i + u_i$$

Where,

'y_i' = The dependent variable, which pertains to pod yield.

'x_i' = The array of independent variables encompassing the number of pods plant^{-1}, 100 kernel weight (grams), Shelling (%), SMK (%), Number of branches plant^{-1}, root dry weight (g) and DMP (g plant^{-1}).

'β' = The slope coefficient associated with each independent variable.

'α' = The constant or intercept term.

'ui' = The error term.

This structured regression model equation may be elegantly reformulated as follows:

Pod yield (Kg ha^{-1}) =

$$\alpha + \beta_1 \text{ no. of pods plant}^{-1} + \beta_2 \text{ 100 kernel weight (g)} + \beta_3 \text{ shelling (\%)} + \beta_4 \text{ SMK (\%)} + \beta_5 \text{ number of branches plant}^{-1} + \beta_6 \text{ root dry weight (g)} + \beta_7 \text{ DMP (g plant}^{-1}\text{)} + u_i$$

RESULTS AND DISCUSSION

Effect of growth characters

Plant height

The application of paclobutrazol had a impact on several key growth parameters, as delineated in Table 1. A clear trend emerged, demonstrating that plant height experienced a gradual reduction as the paclobutrazol concentration increased, with the 200 ppm dosage leading to the most significant decrease (45.7 cm) compared to the control group (62.5 cm). This outcome was consistent with the heights observed with other paclobutrazol concentrations, namely T_4 (150 ppm), T_3 (100 ppm) and T_2 (50 ppm). Notably, when considering different application timings, S_3 (Double spraying at 30 and 50 DAE) resulted in the shortest plants, measuring 49.5 cm, in contrast to the other timings. The observed reduction in plant height due to the double application of paclobutrazol could be attributed to a decrease in the number of stem nodes per plant. The reduction in plant height is likely attributable to the anti-gibberellin action of PBZ, which inhibits cell division and cell elongation processes generally influenced by gibberellins. These findings align with the research conducted by Hegazi and El-Shraiy (2007).

Number of branches and root dry weight

Understanding a crop's branching and root system is vital for comprehending various crop production challenges. The number of branches and the dry root weight of plants exhibited significant variation among the different treatments involving various concentrations of paclobutrazol (Table 1). Among the primary plots, the application of paclobutrazol at 200 ppm resulted in the highest number of branches plant^{-1} (5.0) and the greatest root dry weight plant^{-1} (3.78 g), closely followed by paclobutrazol at 150 ppm (4.8 branches and 3.57 g root dry weight plant^{-1}) when compared to the control group. In terms of the timing of spraying, the treatment involving double spraying at 30 and 50 DAE recorded the highest values for branches plant^{-1} (4.8) and root dry weight plant^{-1} (3.35), followed by single spraying at 50 DAE (4.5 branches and 3.14 g root dry weight plant^{-1}). These findings are in line with the results reported by Lenka *et al*. (2023). The application of paclobutrazol may have contributed to increased root activity, resulting in enhanced root growth and vigor.

Dry matter production

Dry matter production (DMP) in a crop serves as an indicator of its efficiency in utilizing available resources such as solar radiation, moisture, nutrients and other environmental factors. The application of paclobutrazol at 200 ppm resulted in the highest DMP (35.24 g plant^{-1}), followed by paclobutrazol at 150 ppm (33.17 g plant^{-1}) when compared to the other treatments (Table 1). Similarly, when considering different application timings, the application of paclobutrazol at 30 and 50 DAE yielded the highest DMP (34.62 g plant^{-1}), followed by single spraying at 50 DAE. These findings align with the results obtained by Barman *et al*. (2017).

Effect of yield attributes

The various concentrations of paclobutrazol application on groundnut was found to be significant on yield attributes (Table 2). Notably, the application of paclobutrazol at 200 ppm led to the highest pod count per plant (21.7), test weight (54.08 g), shelling percentage (74.8%) and kernels (91.24%). In contrast, the control group exhibited the lowest values for these attributes, with 16.3 pods per plant, a test weight of 49.78 g, shelling percentage of 67.2% and kernels at 85.13%. This could be attributed to paclobutrazol having a substantial influence on enhancing yield-related attributes. The application of PBZ may have facilitated the more efficient conveyance of photosynthates to reproductive parts during pod development stages, leading to these observed outcomes, which are in agreement with the findings of Hua *et al.* (2014). In the context of spraying timing, significantly higher pod count per plant (20.7), test weight (52.71 g), shelling percentage (72.4%) and kernels (91.25%) were recorded in the treatment involving double spraying at 30 and 50 DAE compared to the other treatments.

Yield

The application of paclobutrazol resulted in a significant increase in groundnut yield at various concentration levels,

Table 1: Effect of Paclobutrazol (PBZ) on growth characters of groundnut (Pooled data).

Treatments	Plant height (cm)	Number of branches	Root dry weight (g)	DMP (g plant^{-1})
Concentration of paclobutrazol				
T_1: Paclobutrazol @ 25 ppm	52.1	4.2	3.08	28.98
T_2: Paclobutrazol @ 50 ppm	50.6	4.4	3.19	30.61
T_3: Paclobutrazol @ 100 ppm	48.9	4.6	3.32	31.26
T_4: Paclobutrazol @ 150 ppm	46.8	4.8	3.57	33.17
T_5: Paclobutrazol @ 200 ppm	45.7	5.0	3.78	35.24
T_6: Control	62.5	4.1	2.18	26.82
SEm (±)	1.51	0.1	0.14	1.03
CD (P=0.05)	3.23	0.2	0.38	2.12
Time of application				
S_1: Single spraying at 30 DAE	53.8	4.3	3.14	29.47
S_2: Single spraying at 50 DAE	51.7	4.5	3.23	31.59
S_3: Double spraying at 30 and 50 DAE	49.5	4.8	3.35	34.62
SEm (±)	1.19	0.1	0.07	1.25
CD (P=0.05)	2.41	0.3	0.15	2.61

as detailed in Table 2. All concentrations of PBZ demonstrated superior results compared to the control group. Notably, the treatment involving paclobutrazol at 200 ppm (T_5) yielded the highest pod yield (2724 kg ha^{-1}) and kernel yield (1210 kg ha^{-1}). Following closely behind was the application of paclobutrazol at 150 ppm. When evaluating different application timings, it was observed that the highest pod yield (2568 kg ha^{-1}) and kernel yield (1150 kg ha^{-1}) were achieved when PBZ was applied at both 30 DAE and 50 DAE (S3). Notably, the interaction between these factors resulted in significantly higher yield attributes being recorded in the T_5S_3 treatment combination. Conversely, the treatment combination T_6S_1 exhibited the lowest number of pods plant^{-1}, test weight, shelling % and SMK (%). This variation in canopy coverage, influenced by the decreased plant height due to paclobutrazol application, likely played a role in these yield outcomes. Similar results have been observed in studies conducted by Hua *et al*. (2014) and Barman *et al*. (2017).

Correlation and regression analysis

The mean of growth and yield attributes are graphically illustrated in Fig 1. The correlation results (Table 3) showed that all the variables included in the model were positively significant at 1% level of significance and these signs emphasize all the variables would attribute to the yield of the groundnut. The correlation coefficients between pod yield and various factors, including pods plant^{-1} (0.92), 100 kernel weight (0.79), shelling (0.78), SMK (0.72), number of pods plant^{-1} (0.91), root dry weight (0.91) and DMP (0.94), underscore the strong positive associations among these attributes (Fig 2). This empirical evidence strongly supports the notion that an increase in these variables corresponds to an augmented groundnut yield. The objective of the multiple linear regressions was to quantitatively assess the relationships and elucidate the extent of influence each prescribed parameter exerts on pod yield (Ajaykumar *et al*., 2023). The multiple linear regression equation, consequently derived, is as follows:

Pod yield (Kg ha^{-1}) =

70.87 + 20.56 no. of pods plant^{-1} + 3.33 100 kernel weight (g) + 4.63 shelling (%) + 3.SMK (%) + 191.45 no. of branches plant^{-1} + 250.48 root dry weight (g) + 48.59 DMP (g plant^{-1})

Table 2: Effect of paclobutrazol (PBZ) on yield attributes and yield of groundnut (Pooled data).

Treatments	Pods plant^{-1} (No.)	100 kernel weight (g)	Shelling (%)	Kernel (%)	Dry pod yield (Kg ha^{-1})	Kernel yield (Kg ha^{-1})
Concentration of paclobutrazol						
T_1: Paclobutrazol @ 25 ppm	18.4	50.70	68.9	86.94	2087	913
T_2: Paclobutrazol @ 50 ppm	19.5	51.06	69.2	87.04	2351	1027
T_3: Paclobutrazol @ 100 ppm	19.8	52.25	69.5	88.75	2438	1115
T_4: Paclobutrazol @ 150 ppm	20.9	53.03	74.2	90.01	2547	1180
T_5: Paclobutrazol @ 200 ppm	21.7	54.08	74.8	91.24	2724	1210
T_6: Control	16.3	49.78	67.2	85.13	1898	825
SEm (±)	0.52	1.02	0.21	0.75	75.1	22.5
CD (P=0.05)	1.24	2.10	0.43	1.58	150.3	48.6
Time of application						
S_1: Single spraying at 30 DAE	18.4	50.14	68.7	88.07	2332	965
S_2: Single spraying at 50 DAE	19.5	51.38	70.5	89.54	2403	1042
S_3: Double spraying at 30 and 50 DAE	20.7	52.71	72.4	91.25	2568	1150
SEm (±)	0.61	0.14	0.51	1.01	68.5	21.5
CD (P=0.05)	1.23	0.29	1.04	2.05	140.2	45.8

Table 3: Correlation between pod yield and plant attributes (Pooled data).

Variables	Pod yield (Kg ha^{-1})	Pods plant^{-1} (No.)	100 kernel weight (g)	Shelling (%)	SMK (%)	No. of branches plant^{-1}	Root dry weight (g)	DMP (g plant^{-1})
Pod yield (Kg ha^{-1})	1							
Pods plant^{-1} (No.)	0.92	1						
100 kernel weight (g)	0.79	0.77	1					
Shelling (%)	0.78	0.81	0.68	1				
SMK (%)	0.72	0.72	0.55	0.72	1			
No. of branches plant^{-1}	0.91	0.91	0.81	0.84	0.76	1		
Root dry weight (g)	0.91	0.92	0.71	0.73	0.67	0.82	1	
DMP (g plant^{-1})	0.94	0.93	0.80	0.82	0.77	0.93	0.84	1

Table 4: Multiple linear regression analysis of the groundnut pod yield.

Variables	Coefficient	Std. Err	t-stat	P-value	Signification codes
Intercept	70.87	723.44	0.10	0.92	NS
Pods plant^{-1} (No.)	20.56	7.65	2.69	0.00	**
100 kernel weight (g)	3.33	11.63	0.29	0.78	NS
Shelling (%)	4.63	7.20	0.64	0.52	NS
SMK (%)	3.76	7.22	0.52	0.61	NS
No. of branches plant^{-1}	191.45	87.27	2.19	0.03	*
Root dry weight (g)	250.48	60.63	4.13	0.00	**
DMP (g plant^{-1})	48.59	12.72	3.82	0.00	**

Signification codes: * 5% level of significance, **1% level of significance, NS- Non-significant.

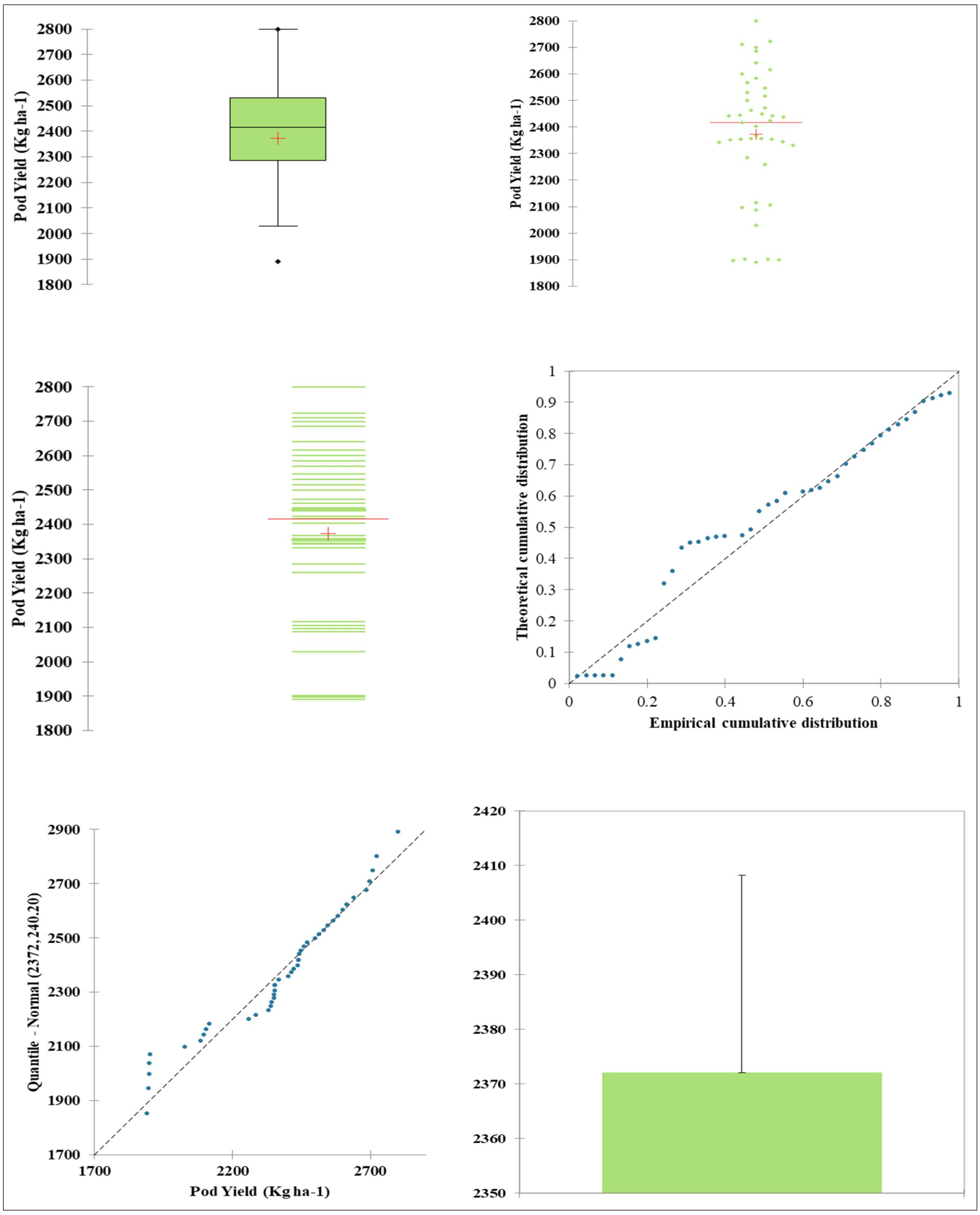

Fig 1: Plots of pod yield (Kg ha^{-1}) of leguminous groundnut.

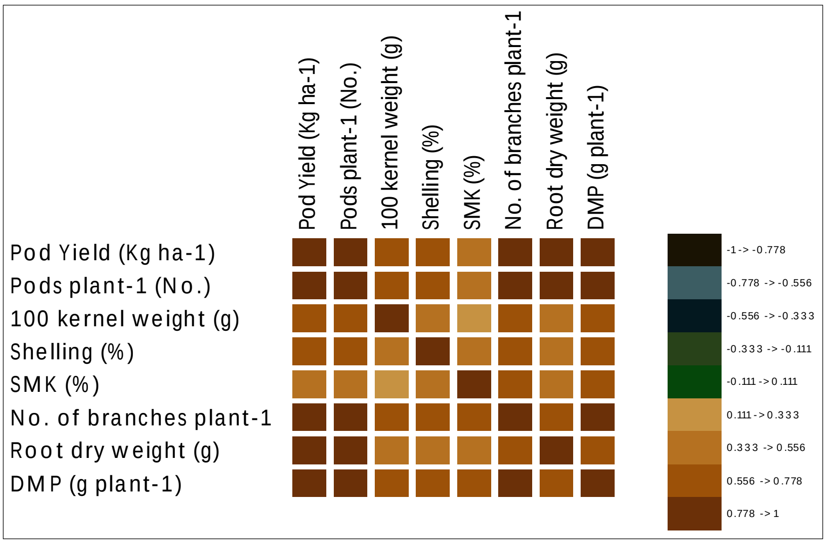

Fig 2: Correlation matrix between pod yield and plant characteristics.

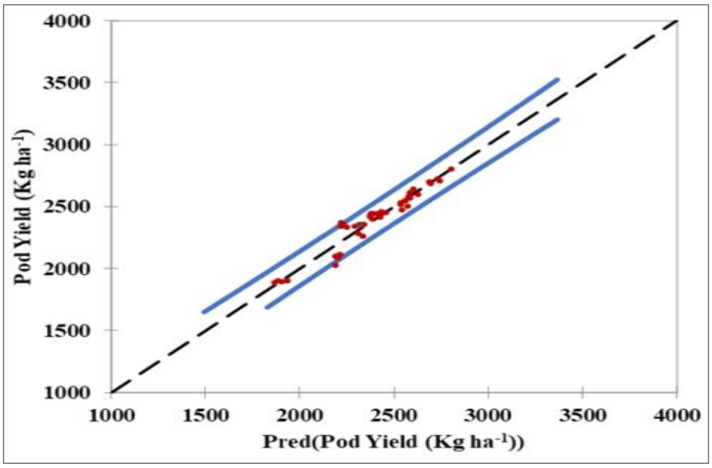

Fig 3: Regression fit: Pod yield *versus* predicted pod yield.

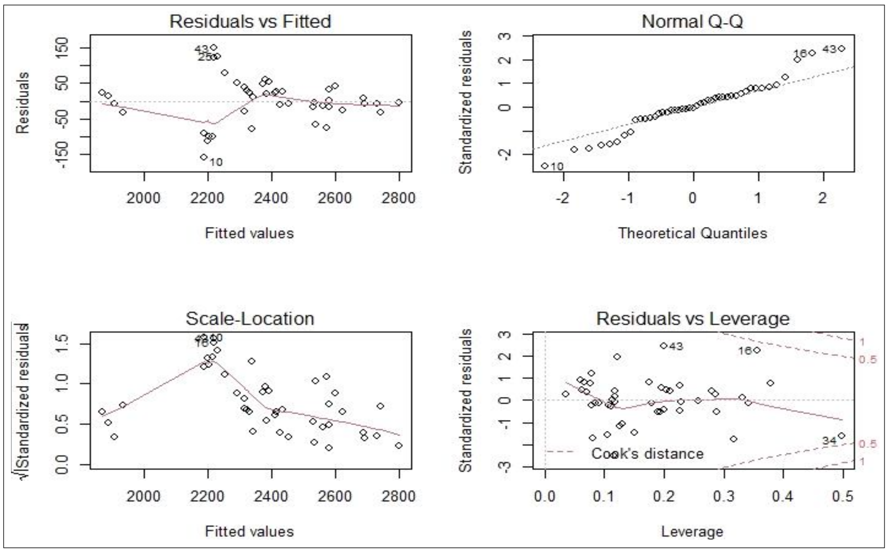

Fig 4: Regression diagnostic plots of groundnut pod yield.

All variables except 100-kernel weight, shelling and SMK, exhibited statistically significant associations. Specifically, the slope coefficient for the number of pods per plant suggests that for every one-unit increase, we can anticipate a substantial 20.56 unit rise in pod yield, assuming all other variables remain constant (Table 4). Similarly, a one-per cent increment in the number of branches plant^{-1}, root dry weight and dry matter production leads to increases of 191.45, 250.48 and 48.59 units in pod yield, respectively, (Tittonell *et al*., 2007). This compelling econometric evidence underscores the significant impact of variables such as the number of pods plant^{-1}, number of branches plant^{-1}, root dry weight and dry matter production on groundnut pod production. Our regression model enabled us to estimate the predicted grain yield, which we compared against field-level pod yield (Fig 3). Additionally, we examined regression diagnostic plots to assess the model's validity. These plots include residual vs. fitted values, normal quantile-quantile (Q-Q) plots, scale-location plots and residuals vs. leverage values. Their consistent patterns reveal that the model maintains constant error variance, adheres to normal distribution assumptions and is free from outliers (Fig 4).

CONCLUSION

Both the years of experiments concluded that the application of paclobutrazol @ 200 ppm concentration at 30 and 50 DAE in groundnut significantly reduced plant height to an optimum level with highest yield. The application of paclobutrazol led to a remarkable increase in yield, up to 36% with increasing PBZ concentration and up to 31% with double application compared to single application. Correlation and regression analyses consistently highlight a positive relationship between all examined parameters and pod yield. The inference of this experiment can be drawn as double spraying at 30 and 50 DAE with 200ppm concentration of PBZ showed positive upshots in case of different yield parameters which ultimately resulted on the yield of groundnut.

Conflict of interest: None.

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