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# CRITICAL LIMITS OF SOIL AVAILABLE PHOSPHORUS FOR RAPESEED (*Brassica campestris* VAR. *toria*) IN ACIDIC SOILS OF MEGHALAYA

Sanjay Swami, Alok Maurya

School of Natural Resource Management, College of Post Graduate Studies, Central Agricultural University, Umiam - 793 103, Meghalaya

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KEYWORDS

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## ABSTRACT

A pot culture experiment was conducted at School of Natural Resource Management, College of Post Graduate Studies, Central Agricultural University, Umiam, Meghalaya during *Rabi* season of 2016-17. The experiment was consisted of 24 treatments *viz.,* 2 types of soil (Alfisol and Inceptisol), 2 sources of P (single super phosphate and Mussoorie rock phosphate) and 6 levels of P (0, 30, 60, 90, 120 and 150 mg P $kg^{-1}$ of soil). Rapeseed (cv. M-27) was raised as test crop. The experiment was conducted in completely randomized design and replicated thrice. The highest mean dry matter yield of rapeseed (16.1 g $pot^{-1}$) was recorded with 120 mg P $kg^{-1}$ of soil ($P_5$). Further increase in the levels of P by 150 mg P $kg^{-1}$ ($P_6$) of soil significantly decreased the dry matter yield by 4.6% over $P_5$. The dry matter yield produced with RP was of lower order as compared to SSP at each levels of P irrespective of soil type. The concentration of P in plant dry matter of rapeseed increased with each successive levels of P in both soils and with both of P sources. The highest soil available P (64 kg $ha^{-1}$) was recorded in Inceptisol with $P_6$ under SSP, whereas the least soil available P (8.2 kg $ha^{-1}$) was recorded in Alfisol with control under RP. The critical limits of available P was established by using LRP model as 38.5 and 31.0 kg $ha^{-1}$ through RP and SSP in Alfisol, whereas in Inceptisol, the critical limits values were recorded as 37.0 and 29.5 kg $ha^{-1}$ under RP and SSP, respectively.

* Corresponding author

E-mail: sanjayswamionline@yahoo.com (Sanjay Swami)

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## 1 Introduction

Oilseed crops are second most important crop next to cereals. India is the 4th largest consumer of edible oils after United States of America, China and Brazil (Parcell et al., 2018). Globally, rapeseed and mustard contributes almost 6 percent of global vegetable oil production, 14 percent of vegetable oil imports and 10 per cent of edible oils (Mir et al., 2010). Rapeseed-mustard ranks second in area and production among all the oilseed crops after groundnut in India. It contributes to the area (4.1 M ha) and production (6.6 Mt) of total oilseed and mustard of India with average productivity of 11.82 q $ha^{-1}$ (Prasad, 2013). It is cultivated in Meghalaya on an area of 9720 ha and production of 9270 tones with productivity of 9.5 q $ha^{-1}$ with the per capita per day oil availability of just 8.0 g that is moderate against the national requirement (Anonymous, 2014).

About 81% soils of this region are acidic in nature out of total cultivated area (Sharma et al., 2006). Acid soil limits the soil phosphorus (P) availability to the crop plants because they have tendency to fix P as iron and aluminium phosphate (Ryden & Pratt, 1980). Adequate P supply based on precise assessment of soil P requirement is therefore crucial to improving crop productivity in the region (Singh et al., 2014). P is essential for energy transformation (fat) especially in oil seed crops and finally, improves the oil content (Fohse et al., 1991). However, at present time, P recommendation for rape seed crop production in this region is unknown. So keeping these views in the mind, an experiment was conducted to find out critical limits of soil available P for rapeseed in acid soils of Meghalaya.

## 2 Material and Methods

A pot experiment was conducted at School of Natural Resource Management, College of Post-Graduate Studies, Central Agricultural University, Umiam, Meghalaya during *Rabi* season of 2016-17. The experiment was consisted of twenty four treatments *viz.*, two types of soil (Alfisol and Inceptisol), two P sources (single super phosphate and Mussoorie rock phosphate) and six levels of P ($P_1$ = 0, $P_2$ = 30, $P_3$ =60, $P_4$ =90, $P_5$ =120 and $P_6$ = 150 mg $kg^{-1}$ of soil). Rapeseed (cv. M-27) was raised as test crop. The experiment was conducted in completely randomized design and replicated thrice. The critical limits of available P were determined by using Linear Response Plateau (LRP) Model proposed by Waugh et al. (1973). Only dry matter yield of rapeseed and available P determined by Bray $P_1$were used for fitting the LRP model for establishment of critical limits of available P. The linear response and plateau lines were established and the point of intersection was used to determine the critical limits of available P.

Two bulk soil samples were collected from the village Bhorym-Bhong (Alfisol) and Umiam (Inceptisol), Ri-Bhoi districts of Meghalaya from 0 to 15 cm soil depth. The soil sample was dried and ground to pass through 2 mm stainless steel sieve to remove gravels and other materials for conducting pot culture experiment. Physio-chemical properties of the collected soils were estimated using standard methods as mentioned against each parameter and are presented in Table 1.

Seventy two plastic pots of 10 kg capacity were filled with two types of soils after performing sterilization. According to the

Table 1 Physio-chemical properties of experimental soils

| Parameters | Soil 1 (Alfisol) | | | | Soil 2 (Inceptisol) | | | | Method used |
|---|---|---|---|---|---|---|---|---|---|
| Soil texture | Sandy loam | | | | Sandy clay loam | | | | International pipette method (Olmstead et al., 1930) |
| pH | 4.86 | | | | 5.02 | | | | pH meter with glass electrode (Piper, 1966) |
| Organic carbon (%) | 1.1 | | | | 1.3 | | | | Rapid titration method (Walkley & Black, 1934) |
| CEC (meq 100 g $soil^{-1}$) | 2.8 | | | | 3.7 | | | | Ammonium acetate saturation method Jackson (1973) |
| Available Nitrogen (kg $ha^{-1}$) | 275.0 | | | | 350.0 | | | | Alkaline potassium permanganate method (Subbiah & Asijah, 1956) |
| Available Phosphorus (kg $ha^{-1}$) | 8.0 | | | | 13.0 | | | | Bray and Kurtz No. 1 method (Bray & Kurtz, 1945) |
| Available Potassium (kg $ha^{-1}$) | 259.8 | | | | 280.0 | | | | Neutral Normal Ammonium Acetate Method (Knudsen et al., 1982) |
| Available Sulphur (kg $ha^{-1}$) | 14.3 | | | | 18.5 | | | | $CaCl_2$-extractable S (Chesnin & Yien 1951) |
| Available micronutrients (mg $kg^{-1}$ soil) | Zn | Cu | Mn | Fe | Zn | Cu | Mn | Fe | DTPA Method (Lindsay & Norvell, 1978) |
| | 0.53 | 2.1 | 3.0 | 12.32 | 0.61 | 2.5 | 3.45 | 9.81 | |

treatments the amount of P was supplied through the single super phosphate (SSP) and rock phosphate (RP) and posts were kept in polyhouse. The seed of test crop (rapeseed variety M-27) was obtained from ICAR Research Complex for NEH Region, Barapani, Meghalaya. The crop was sown on 5$^{th}$ November, 2016 and it was harvested on 24$^{th}$ January, 2017 at physiological maturity stage and dry matter yield was recorded. Plant samples were collected from each pot for chemical analysis. The samples were dried in an oven and then grinded thoroughly with grinder and preserved separately in sealed and labelled containers. 0.5 g oven dried plant samples were digested and the P concentration in the digested plant samples was determined yellow colour development method using spectrophotometer at 420 nm wave-length. The uptake of P by rapeseed was worked out by using the following formula:

**P uptake by plant (kg ha$^{-1}$) = Per cent nutrient concentration in rapeseed X dry matter yield (t ha$^{1}$) x 10**

The Data obtained from the experiment were subjected to statistical analysis (ANOVA) and significant difference was calculated at 5% level of significance (Fisher, 1958).

## 3 Results and Discussion

### 3.1 Dry matter yield

The mean plant dry matter yield increased significantly with the increasing levels of P up to 90 mg of P kg$^{-1}$ soil however, the highest mean dry matter yield of rapeseed (16.1 g pot$^{-1}$) was recorded with the application of 120 mg of P kg$^{-1}$ of soil. Further increase in the dose of P by 150 mg of P kg$^{-1}$ soil significantly decreased the dry matter yield by 4.6 % over 120 mg of P kg$^{-1}$ (Table 2). The dry matter yield produced with RP was of lower order as compared to SSP at each levels of P irrespective of soil type. Among various two ways and three way interaction, all the interactions were found to be significant. This enormous response in dry matter yield with the application of P was due to low available P status of the experimental soil. It revealed the optimum mean dry matter yield recorded with 90 mg P kg$^{-1}$ soil was 2.44 times more than the control where no P was applied. It also revealed the high intensity of responsiveness of rapeseed crop to P fertilization.

Results of dry matter yield are in agreement with the findings of Singh & Bishnoi (1994) and Yousaf et al. (2017) who reported

Table 2 Effect of P sources and levels of P on dry matter yield of rapeseed (g pot$^{-1}$) in two types of soils

| P levels mg kg$^{-1}$ soil | Alfisol | | Inceptisol | | Mean |
|---|---|---|---|---|---|
| | RP | SSP | RP | SSP | |
| 0 | 5.57 | 6.00 | 7.02 | 7.20 | 6.45 |
| 30 | 9.34 | 10.30 | 10.77 | 11.89 | 10.58 |
| 60 | 12.12 | 13.20 | 14.14 | 15.61 | 13.77 |
| 90 | 14.21 | 15.00 | 16.13 | 17.68 | 15.76 |
| 120 | 14.44 | 15.20 | 17.02 | 17.81 | 16.11 |
| 150 | 14.12 | 14.90 | 15.80 | 16.65 | 15.37 |
| RP | 12.56 | Alfisol | 12.03 | | |
| SSP | 13.45 | Inceptisol | 13.98 | | |
| S.E(m)± | 0.14 | | | | |
| CD (p=0.05) | 0.39 | | | | |

| For Source of P and Soils | | Interaction | | | |
|---|---|---|---|---|---|
| | | S x So | S x L | So x P | S x So x L |
| S.E(m)± | 0.08 | 0.11 | 0.19 | 0.19 | 0.28 |
| CD (p=0.05) | 0.23 | 0.32 | 0.55 | 0.55 | 0.78 |

RP: Rock Phosphate, SSP: Single Super Phosphate, S: Sources of P, So: Soils, L: Levels of P that the P application to the soil, varying from low to high in available P, increased dry matter yield of sunflower and rapeseed, respectively. The interaction between different levels of applied P and different rapeseed growing soils of Meghalaya was significant in dry matter yield of rapeseed. It depicted the P deficiency of soil and high response of P application in rapeseed. These results are in conformity with those reported by Tyagi & Rana (1992) who observed that with the application of P fertilizer, the yield of mustard crop significantly increased up to 80 kg $P_2O_5$ $ha^{-1}$ which was at par with 100 kg $P_2O_5$ $ha^{-1}$. Similar results were also reported by Prabhuraj et al. (1993) in sunflower.

### 3.2 Phosphorus content

Data from the Table 3 revealed that there was a significant increase in concentration of P by different sources with the increasing levels of applied P in two rapeseed growing acidic soils of Meghalaya. The lowest mean of P content (0.15 per cent) was recorded in control where no P fertilizer was applied, which was significantly increased with the progressive increase in the doses of applied P up to 150 mg P $kg^{-1}$. The concentration of P at each respective levels of applied P was higher in Inceptisol as compared to Alfisol. The highest mean P concentration was observed in Inceptisol (0.35 per cent) with SSP application whereas in Alfisol it was recorded (0.30 per cent). A glance of the data presented in Table 3 revealed that there was a significant increase in concentration of P with the increasing levels of applied P. Among various two way and three way interactions, all the interactions were found to be significant.

This increasing P concentration might be due to the availability of more P in soils with the application of P as well as due to initial available P status in the experimental soils. Singh et al. (1997) and Yousaf et al. (2017) also observed that the concentration of P was significantly improved in both straw and seed of sunflower and rapeseed, respectively upon the increased levels of applied P. Similar results were also obtained by Schultz et al. (2018) for sunflower in North Dakota. The concentration of P was significantly lower in plants grown in Alfisol as compared to Inceptisol. The lower concentration of P is due to less native soil P in these soils.

Table 3: Effect of P sources and levels of P on P content (%) of rapeseed in two types of soils

| P levels | Alfisol | | Inceptisol | | Mean |
|---|---|---|---|---|---|
| | RP | SSP | RP | SSP | |
| 0 | 0.12 | 0.14 | 0.16 | 0.18 | 0.15 |
| 30 | 0.14 | 0.17 | 0.21 | 0.23 | 0.19 |
| 60 | 0.18 | 0.20 | 0.25 | 0.27 | 0.23 |
| 90 | 0.24 | 0.25 | 0.28 | 0.31 | 0.27 |
| 120 | 0.27 | 0.29 | 0.30 | 0.33 | 0.30 |
| 150 | 0.28 | 0.30 | 0.31 | 0.35 | 0.31 |
| RP | 0.23 | Alfisol | 0.22 | | |
| SSP | 0.25 | Inceptisol | 0.26 | | |
| S.E(m)± | 0.01 | | | | |
| CD (p=0.05) | 0.02 | | | | |
| For Source of P and Soils | | Interaction | | | |
| | | S x So | S x L | So x P | S x So x L |
| S.E(m)± | 0.001 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (p=0.05) | 0.01 | 0.02 | 0.03 | 0.03 | 0.04 |

RP: Rock Phosphate, SSP: Single Super Phosphate, S: Sources of P, So: Soils, L: Levels of P

Table 4 Effect of P sources and levels of P on post-harvest P availability in two types of soils

| P levels | Alfisol | | Inceptisol | | Mean |
|---|---|---|---|---|---|
| | RP | SSP | RP | SSP | |
| 0 | 8.2 | 9 | 10 | 12 | 9.8 |
| 30 | 21.7 | 25 | 19 | 28 | 23.43 |
| 60 | 33.3 | 36 | 31 | 38 | 34.58 |
| 90 | 42.6 | 47 | 42 | 49 | 45.15 |
| 120 | 48 | 52 | 52 | 57 | 52.25 |
| 150 | 54 | 58 | 60 | 64 | 59 |
| RP | 35.15 | Alfisol | 36.23 | | |
| SSP | 39.58 | Inceptisol | 38.5 | | |
| S.E(m)± | 1.01 | | | | |
| CD (p=0.05) | 2.87 | | | | |
| For Source of P and Soils | | Interaction | | | |
| | | S x So | S x L | So x P | S x So x L |
| S.E(m)± | 0.58 | 0.82 | 1.43 | 1.43 | 2.02 |
| CD (p=0.05) | 1.66 | 2.34 | 4.06 | 4.06 | 5.74 |

RP: Rock Phosphate, SSP: Single Super Phosphate, S: Sources of P, So: Soils, L: Levels of P

**3.3 Available Soil phosphorus**

The mean of available P increased significantly with the increasing levels of P up to 150 mg P $kg^{-1}$ soil, however, the highest mean available P after harvest of rapeseed (59 kg $ha^{-1}$) was recorded from the pots treated with 150 mg P $kg^{-1}$ of soil. Among various two way and three way interactions, all the interactions were found to be significant. Data related to post-harvest available P provided in Table 4. The possible reason about the post-harvest available P may be due to low phosphorus use efficiency. In general P use efficiency is 10-20% of the soil applied phosphorus. Similar trend was also reported by Yadav et al. (2015) and Yousaf et al. (2017).

**3.4 Critical limits of soil available P**

In order to demarcate the soils on the basis of their responsiveness and non–responsiveness or relatively less responsiveness, the critical limits of available P were determined. The Linear Response Plateau (LRP) model proposed by Waugh et al. (1973) was employed to establish the critical limit of available P for predicting the response of applied P fertilizer to rapeseed (cv. M-27). The response to each nutrient all interpreted separately by using the threshold and plateau yield levels in this model. The application of nutrient results in yield response having a starting point *i.e.* threshold yield and ending point i.e. plateau yield. There was significant relationship between dry matter yield and available P determined by Bray's $P_1$ soil test method (Bray & Kurtz, 1945). The only dry matter yield and available P determined by Bray $P_1$were used for fitting the LRP model for establishment of critical limits of available P. The linear response and plateau lines were established and the point of intersection was used to determine the critical limits of available P. The critical limits of available P presented graphically in Figure 1, 2, 3 and 4.

There were positive relationship between dry matter yield and available P determined by Bray's $P_1$ soil test method. Therefore,

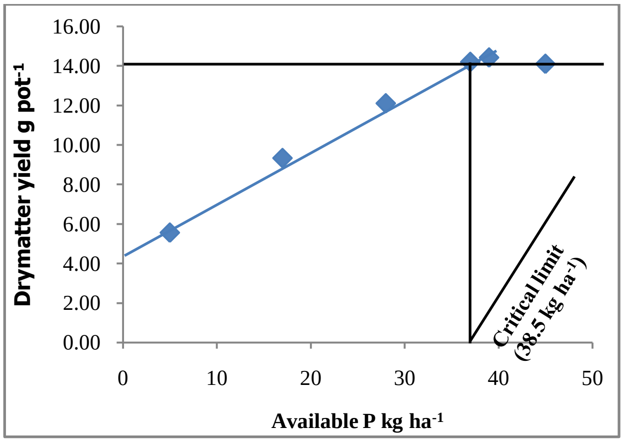


Figure 1 Critical limit of available P for Rapeseed in Alfisol under RP (kg ha$^{-1}$)

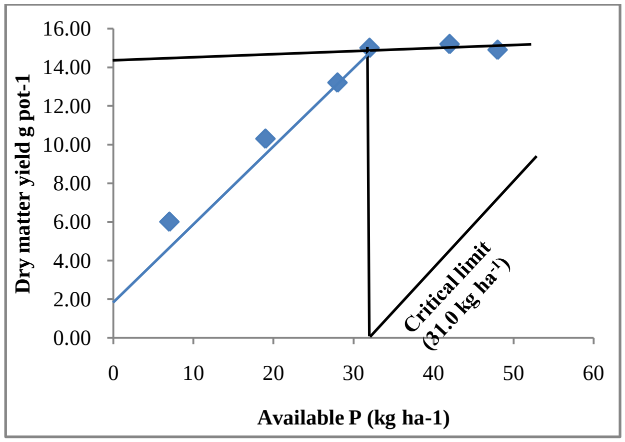


Figure 2 Critical limit of available P for Rapeseed in Alfisol under SSP (kg ha$^{-1}$)

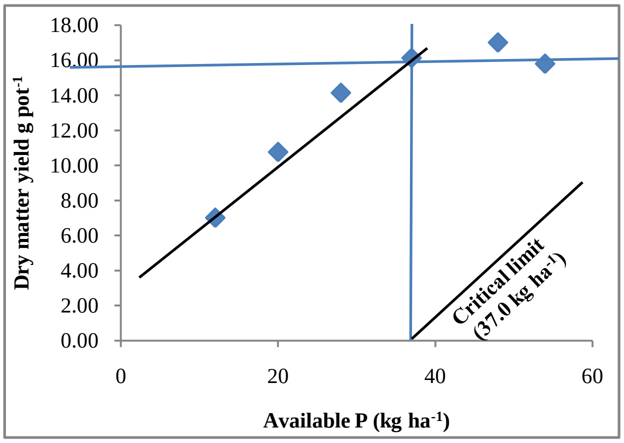


Figure 3 Critical limit of available P for Rapeseed in Inceptisol under RP (kg ha$^{-1}$)

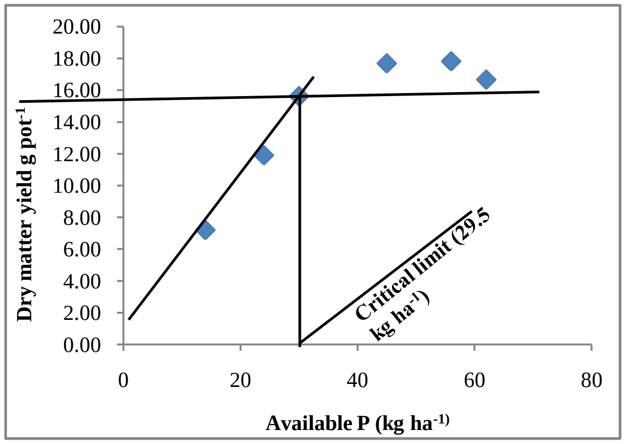


Figure 4 Critical limit of available P for Rapeseed in Inceptisol under SSP (kg ha$^{-1}$)

only dry matter yield and Bray's $P_1$ were used for fitting the LRP model for establishment of critical limits of available P in acidic soils of Meghalaya. The critical limits of available P for rapeseed (cv. M-27) were established by Bray's $P_1$ soil test for Inceptisol and Alfisol, respectively. The critical limit of kg ha$^{-1}$ by Bray's $P_1$ soil test in Inceptisol and Alfisol for the rapeseed crop in the present study was higher than 10.00 kg Olsen's P ha$^{-1}$ for ground nut crop reported by Patel et al. (1992). However, Singh & Singh (1983) reported that the critical limits of Olsen's extractable P for bajra and barley were 12.7 and 12.2 kg P ha$^{-1}$ respectively.

## Conclusion

The application of P at lower levels resulted in significant increase in dry matter yield of rapeseed under both the P sources, irrespective of soils. The significant increase in dry matter yield with the application of P was due to the low P available status of the experimental soils and high responsiveness of rapeseed to P application. The application of P with 30, 60 and 90 mg P kg-1 soil significantly and markedly increased the dry matter yield of rapeseed crop in Inceptisol and Alfisol. The P concentration increased significantly and progressively with the increasing levels of applied P. There was successive increase in P absorption by the rapeseed crop with each levels of increment of applied P. The critical limit of available P for rapeseed were established using Linear Response and Plateau (LRP) model as 38.5 kg P ha$^{-1}$ under RP and 31.0 kg ha$^{-1}$ under SSP in Alfisol, whereas in Inceptisol, the critical limits of available P were established as 37.0 kg Pha$^{-1}$ under RP and 29.5 kg ha$^{-1}$ under SSP. The present investigation indicated that below these critical limits in respective acidic soils, farmer may get definite response to applied P through respective P sources and above these critical limits, and they may get very little response or may not get response at all. Therefore, the farmers will have to apply higher P fertilizer doses in these soils for obtaining the optimum yield of rapeseed.

**Conflict of Interest**

The authors declare that there is no conflict of interest regarding the publication of this research paper.

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