International Journal of Plant & Soil Science

34(3): 83-91, 2022; Article no.IJPSS.82786
ISSN: 2320-7035

Agronomic Yield Performance of Rape and Assessment of Discrimination of Soil Fertilizer Amendments on Genotypic Responses

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Authors' contributions

This work was carried out in collaboration between both authors. Author MM undertook the research, writing of the manuscript and interpretation of data. Author LT helped in performing the statistical analysis and in planning for the execution of research guided the interpretation process and proof read the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i330849

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/82786

Original Research Article

Received 06 December 2021
Accepted 13 February 2022
Published 16 February 2022

ABSTRACT

Aim: The objectives of the study were to (i) assess agronomic performance of rape (*Brassica napus* L.) genotypes under different soil amendments and seasons and (ii) identify the most discriminating soil fertilizer amendment on genotypic responses of rape.
Study Design: The experiment was laid as a split plot design with 3 replications in each season.
Place and Duration of Study: The study was undertaken in Monze district, southern province, Zambia in winter and summer periods of 2020/2021 cropping season.
Methodology: The soil fertilizer amendment combinations were the main plots and rape varieties (English Giant [ENG], Hobson [HOB] and Rampart [RAM]) were laid as subplots. Giving a total of 54 experimental units per season. The amendments constituted combinations of raw dung type and artificial fertilizer. The quantitative data, on biomass, breadth, height and leaf count were measured at six weeks after transplanting.
Results: Across seasons, soil amendment and genotypic main effects exhibited significantly responses with regards to biomass and leaf count (P = 0.05). Furthermore, the agronomic genotypic performance showed that RAM was the worst performer. The genotypic response to measured agronomic parameters was better in Raw Cow-Dung plus Cow- Dung Ash (RCD + CDA)

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soil fertilizer amendment than others. Interestingly RCD + CDA was the common discriminating amendment in summer and winter trials.
Conclusion: Rape genotypes performed relatively better in summer than in winter season. The genotype English giant rape and Hobson were better performers across seasons and soil fertilizer amendments. The combination of RCD + CDA was the common discriminating amendment in both summer and winter trials.

Keywords: Brassica napus L.; soil nutrients; biplot analysis; biomass.

1. INTRODUCTION

Rape (*Brassica napus* L) is a leaf vegetable which belongs to the *Brassicaceae* family. It is an important source of nutrients for humans and that includes the beneficial plant's metabolites, such as vitamins, fibres, sulfur-containing glucosinolates among others [1, 2, 3]. It is one of the commonly grown vegetable and it's sold on local markets in most Zambian places. Generally the quality and quantity of biomass is what influences pricing and other agronomic trait factors play little or no role on its cost. In Zambia it ranks second from tomato (*Lycopersicum esculatum* L.) in providing income among small scale farmers on vegetable crops [4].

Rape can grow in a wide range of temperature (0°C to 29°C) with the optimum growing temperature range of between 15°C and 22°C. It requires soils that range from sandy loam to clay loam soils and a continuous supply of water throughout the growing season gardeners [4, 5]. However, rape produced in Zambia is not enough to meet local demand and in addition it's a perishable product.

To achieve high yields in rape vegetable gardening, balanced soil nutrients are required [6]. In addition, the year round production of rape requires land use intensification and the enterprise is only feasible and profitable when soil nutrients depleted during crop production are replenished [7, 8]. In Zambia, the two categorical rape production seasons are summer and rainy season (April to August) and the winter and dry season (September to February). Due to continuous cropping, most soils have become infertile due to removal of crop residues from the fields, coupled with low rates of macro-nutrient applications [9, 10]. Therefore, the replenishment of depleted nutrients is required. In Zambia, combinations of raw cow-dung, chicken droppings, goat manure and artificial fertilizers have been used for soil nutrient replenishment, but their effect on yield and nutrient content is yet to be established [11]. There is therefore, need to evaluate the effect of animal-based soil amendment combinations. Previous studies have shown that genotype by environmental interaction performance exists in rape, implying that discriminating and representative environments can be identified using biplot analysis [12, 13]. In this study evaluation of the interaction of rape genotype by soil amendment (utilized as environments) using biplot analysis will be undertaken. Soil amendment combination capable of discriminating genotypes can be employed by vegetable breeders in selecting for appropriate genotypes. The objectives of the study were therefore to i) assess agronomic performance of rape (*Brassica napus* L.) genotypes under different soil amendments and seasons and ii) identify the most discriminating soil amendment on genotypic response of rape.

2. MATERIALS AND METHODS

2.1 Experimental Site and Land Preparation

The experiment was conducted in Monze district (16.2803^{o} S, 27.4733^{o} E) for two seasons: during winter period (April to August), 2020 and in summer (September to February) during the 2020/ 2021 cropping season (Table 1). The plants were watered as needed. The land was cleared and primary tillage was done by digging up to approximately 30 cm deep using a pick. Secondary tillage was then carried out using a hoe to get a fine tilth.

2.2 Management and Conduct of Experiments

Three genotypes English Giant, Hobson and Rampart obtained from Starke Ayres (PVT) LTD Gauteng South Africa, East African Seed Company in Kenya and African Seed Company in Zambia respectively were used in this study. These genotypes were purposely chosen being the popular and most preferred by farmers. Prior to evaluation genotypes were initially planted in the nursery before they were transplanted to the experimental plots at approximately 30 days after germination. The rape genotypes were evaluated in five fertilizer soil amendments including a control [non-nutrient applied (NNA)].

These amendments were sources of nutrients and are as stated: 1) Artificial fertilizers (AF), 2) raw cow-dung plus cow-dung ash (RCD+CDA), 3) raw cow-dung (RCD), 4) cow-dung ash (CDA) and 5) combination of artificial fertilizer, raw cow-dung and cow-dung ash (AF+RCD+CDA). The experiment was laid as a split plot design in both seasons with three replications. That's soil fertilizer amendments as the main plot and variety as a subplot. Giving a total of 54 experimental units per season. Each variety was planted to one row plot of 4 m long with 30 cm spacing within row and 30 cm between rows.

2.2.1 Chemical composition of the applied soil amendments

The chemical composition of the six soil amendments samples collected as a representative of three replications were evaluated at the University of Zambia, School of Agricultural Sciences and the results are shown in Table 2.

2.2.2 Application rates of applied soil amendments

Raw Cow Dung plus CDA combination was composed as a mixture of RCD and CDA in the ratio of 1:1. The amendment of AF+RCD+CDA were combined in the ratio 1: 20:20. In this experiment, an artificial vegetable fertilizer, compound D (N: 10%, P_2O_5: 20%, K_2O: 20%, S: 6%) was utilized. All soil amendments were applied at a rate of 1250 kg/ha except for artificial fertilizer amendment which was applied at a rate of 125 kg/ha. Appropriate standard cultural practices such as weeding and spraying for pest were undertaken.

2.3 Data Collection

Agronomic data was collected on four parameters: height, leaf count, breadth and biomass on all the 54 experimental units for both experimental layouts (winter and summer trials). Data was recorded as a mean of all plants in a row except for biomass were it was taken as a total of 8 plants involved.

Table 1. Environmental conditions of an experimental site in Monze during 2020/2021 cropping seasons

Average conditions	Summer (Sep-Feb)	Winter (Apr-Aug)
Minimum temperature	20°C	04°C
Maximum temperature	39°C	25°c
pH	6.5	6.5
Soil type	Sand to loam	Sand to loam
Humidity	60	80
UV index	7 high	5 high
Wind speed	18km/h	23km/h
Sun rise	6:01 AM	6:39AM
Sun set	6:06PM	5:47PM

(Source: https://www.accweather.com), UV-ultra-violet

Table 2. Selected chemical composition of soil amendments used in the study

Amend	pH	OM %	N%	P*	K%	Na*	Ca %	Mg*	Zn*
AF	6.64	5.36	1.23	182.65	0.87	0.12	4.07	1.54	8.18
RCD+CDA	8.03	7.92	1.04	199.64	3.63	0.22	5.96	2.63	8.50
RCD	7.78	8.48	0.70	161.41	2.84	0.22	5.51	1.92	6.80
CDA	8.22	6.16	0.45	220.87	3.13	0.26	8.14	3.19	8.30
NNA	7.15	5.12	0.67	126.79	0.61	0.16	3.95	1.10	9.64
AF+RCD+CDA	7.56	7.44	0.48	144.42	3.07	0.19	4.31	2.15	7.74

*AF- Artificial Fertilizer. RCD- raw cow-dung, RCD+CDA-raw cow-dung plus cow-dung ash, CDA- cow-dung ash, AF+RCD+CDA- artificial fertilizer, raw cow-dung plus cow-dung ash. Amend- Soil fertilizer Amendment. pH-potential of hydrogen. N- Nitrogen, P- Phosphorus, K- Potassium, Na- Sodium, Ca- Calcium, Mg- Magnesium, *-mg/kg- milligram per kilogram*

A ruler and a measuring tape were used to take the leaf height and breadth respectively on all the 54 experiment units per season. The height measurements were taken from the beginning of the leaf stalk to the tip of the largest leaf of an individual plant and recorded as the average of all plants in the row. For leaf breadth the middle cross section of the lamina or leaf blade was measured at six weeks as an average of plants in a row. Leaf count was taken through actual counting of the leaves on each plant and mean per row was recorded.

Eight plants from individual unit plots were harvested or plucked, tied in bundles and then their masses were determined by measuring with an electronic balance. Leaf biomass was taken on the sixth week immediately after measuring the height, breadth and leaf count in grams using electronic and spring balances for all 54 experimental units.

2.4 Data Analysis

Data on agronomic traits was computed using analysis of variance (ANOVA) assuming a fixed model. Location, variety and soil amendment (fertilizer combination) means were separated using fisher protected Least Significant Difference (LSD) method, at a significant level of α = 0.05. Further exploration on interaction of genotype x soil amendment in each season was undertaken on biomass being a key parameter using a GGE biplot, meta-analysis tool. All the data analysis was carried out using GenStat statistical package (18^{th} Edition).

3. RESULTS

3.1 Genotypic and Soil Amendment Effect on Rape Genotypes across Seasons

The results showed that with regards to seasonal main effect, there was no differences in the mean performance on all measured parameters across amendments and variety except for height (P = 0.001) (Table 3). Further analysis showed that the mean height performance across amendments and varieties was higher in summer than in winter exhibiting a mean score performance of 28.6 and 14.1 respectively ($LSD_{(\alpha = 0.05)}$ =2.4). Interestingly there were differences in genotypic and soil amendment main effects responses on all measured parameters except for height.

Furthermore, the mean performance of variety across season and amendments showed that RAM was a generally poorest performer (Table 4). On the other aspect, parameter responses in RCD+CDA soil amendment performed better than others (Table 5).

The interaction of genotype and season across amendments generally showed that the mean biomass performance was relatively higher in summer than in winter (Fig. 1) for all the three genotypes (Fig. 1).

3.2 Delineation of Soil Fertilizer Amendment with Regards to Genotypic Biomass Performance in Winter

The combinations of .AF+RCD+CDA and RCD+CDA were the most discriminating amendment in terms of genotypic performance with regards to biomass mean response in winter as evidenced by the longer environment vector (Fig. 2). The amendment, CDA was identified as a representative environment, as evidenced by a smaller angle between location vector and the average environmental coordinate (AEC). Hobson rape performed better in RCD+CDA. English giant rape was the better performer on AF+RCD+CDA when compared to other soil fertilizer amendments. All the three genotypes exhibited similar performance in CDA soil amendment with regards to mean biomass response.

3.3 Delineation of Soil Fertilizer Amendment with Regards to Genotypic Biomass Performance in Summer

The combination of RCD+CDA was the most discriminating amendment in terms of genotypic biomass performance in summer (Fig. 3) as evidenced by the longer environment vector (Fig. 3). On the other hand, RCD and AF were identified as a representative amendment, as evidenced by a smaller angle between location vector and the average environmental coordinate (AEC). Just like a winter trial, HOB performed better in RCD+CDA soil amendment when compared to other soil fertilizer amendments.

4. DISCUSSION

Rape vegetable is an important source of nutrition and income in Zambia. In this research, different soil amendments and rape genotypes were evaluated with a view of investigating yield responses. Significant interactional effect between 'genotype' by 'season' with regards to biomass, breadth and leaf count were obtained. Further consideration on biomass a key parameter showed that the general performance of genotypic biomass response was higher in summer than winter (Fig 1). The difference could be due to prevailing temperature differences at that time. Winter and summer season experienced lowest temperatures of 4 and 20^0 respectively during the cropping season (Table 1). Prevailing temperature is a direct function of growing degree days experienced in a particular period and hence plant growth [14].

Table 3. Mean squares of measured parameters across winter and summer rape growing seasons in Monze

SOV	d.f.	Parameter MS			
		Biomass (g)	Breadth(cm)	Count	Height (cm)
Season	1	129722.7	2.37	1.56	5647.8***
Rep/Location	4	78768.8	4.8	1.6	19.537
Amend	5	371105.3***	5.289*	4.52**	10.698
Amend x Season	5	40190.2***	5.615*	1.4981	37.543*
Error	20	3238.1	1.596	0.8926	9.526
Variety	2	46429.6***	5.861*	6.1204***	4.704
Amend x Variety	10	27070.7***	1.55	1.92*	4.126
Variety x Season	2	1784.5*	3.954*	0.8426	6.259
Amend x Variety x Season	10	10927.7***	1.931	2.58***	4.881
Error	48	487.1	1.213	0.7176	5.125

*Significant at P= 0.05; **-P= 0.01 and ***-P= 0.001. MS=means square. SOV- Source of variation; MS- Mean square*

Table 4. Mean genotypic performance of rape genotypes across amendments and seasons

Variety	Biomass (g)	Breadth(cm)	Count	Height (cm)
ENG	351.9	5.14	4.72	20.97
HOB	348	5.5	4.17	21.69
RAM	237.9	4.69	3.92	21.31
LSD $_{(\alpha = 0.05)}$	10.46	0.52	0.4	

ENG-English giant rape, HOB=Hobson rape, RAM=Rampart rape. LSD=least significant difference

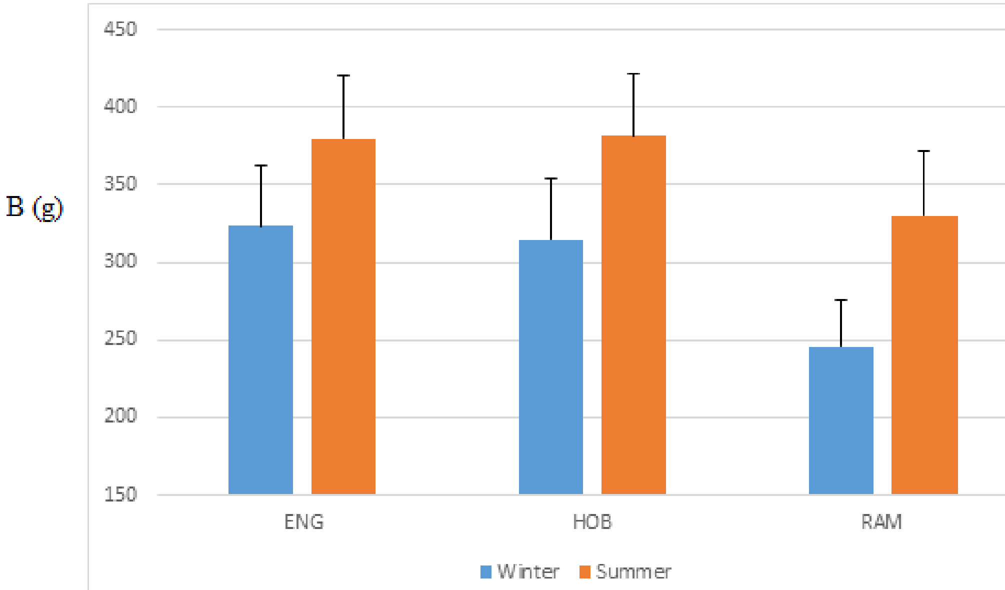

Fig. 1. Response of biomass to interaction of 'Genotype x Season' across soil amendments
ENG=English giant rape, HOB=Hobson rape, RAM=Rampart rape, B- Biomass, g- grams, Bars- Error bars

Table 5. Mean parameter performance of rape genotypes across genotypes and season

Amendment	Biomass(g)	Breadth(cm)	Count	Height (cm)
AF	247.7	5.17	4.167	21.33
AF+RCD+CDA	439.1	5.94	4.556	22.11
CDA	319.8	4.89	3.944	20.5
NNA	91.6	4.28	3.556	20.28
RCD	395.1	5.11	4.389	21.89
RCD+CDA	482.3	5.28	5	21.83
LSD (α = 0.05)	39.57	0.88	0.66	

AF- Artificial Fertilizer. RCD- raw cow-dung, RCD+CDA-raw cow-dung and cow-dung ash, CDA- cow-dung ash, AF+RCD+CDA- artificial fertilizer, raw cow-dung and cow-dung ash, NNA- non-nutrient applied. LSD-least significant differences

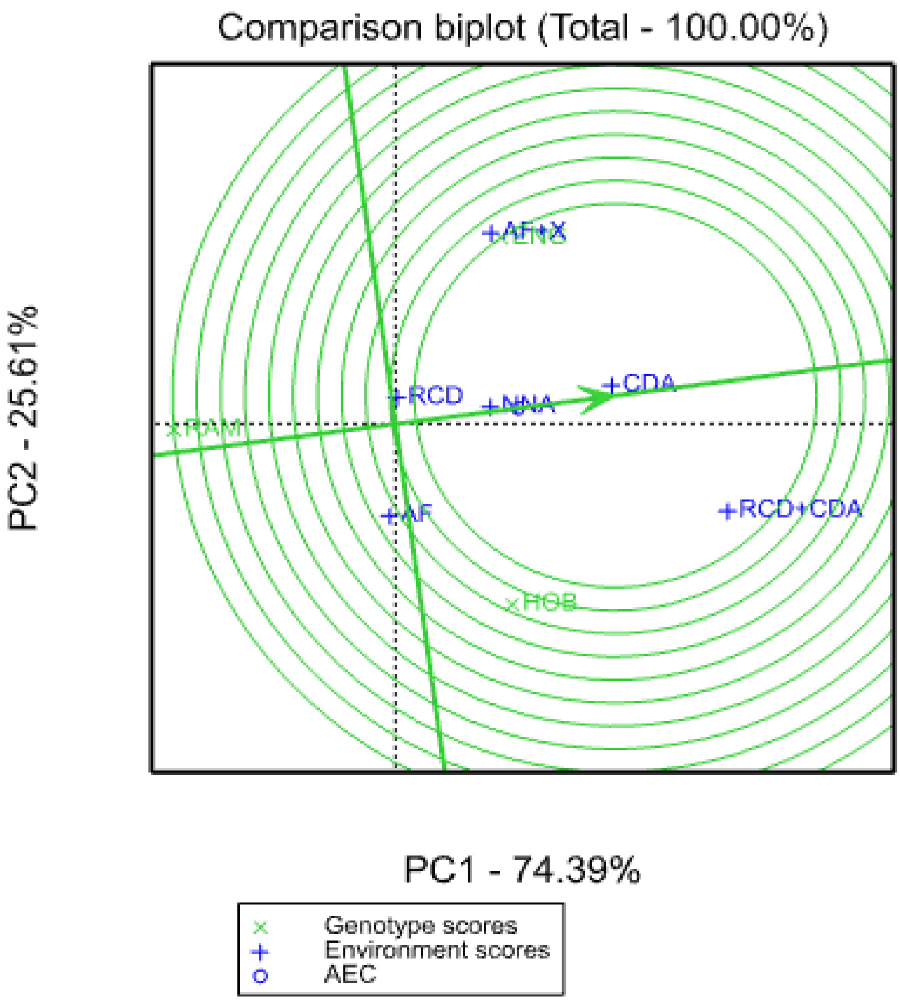

Fig. 2. Biplot showing delineation of soil amendments with regards to biomass in winter

CDA- cow-dung ash, RCD- raw cow-dung, NNA- non-nutrient applied, AF-artificial fertilizer, AF + X - AF+RCD+CDA. HOB, RAM and ENG are rape genotypes Genotype-Green cross symbol, Environments- Blue plus symbol

Furthermore, the mean performance of variety across season and amendments showed that English giant and Hobson rape were clearly better performers. This results coincide with an earlier study by Ganya et al. [15] who also found out the genotypes English giant and Hobson were high yielding genotypes. In this regard these two genotypes can be recommended as they can guarantee high yields and ultimately high income to farmers. On the other aspect, the general parameter response in RCD+CDA soil amendment were better than other soil amendments (Table 5). This implies that the ultimate performance of rape could be influenced by the environment (as observed by the variations in parameter responses among soil amendments and the genetic make-up (as observed by the consistent mean performance of RAM [Table 4]). These observations concur with earlier findings by Nowosad, et al. [12]. Furthermore the better genotypic performance in RCD+CDA medium as compared to other added soil fertilizer amendments across genotypes may be due to differences in soil element composition and medium pH concentration. Previous studies have demonstrated that the availability of nutrients can be affected by nutrient/ element interactions and pH in the medium [16, 17, 18 19]. In addition, the presence of micro-organisms and their activities also depend on alkalinity and acidity level in the soil [20].

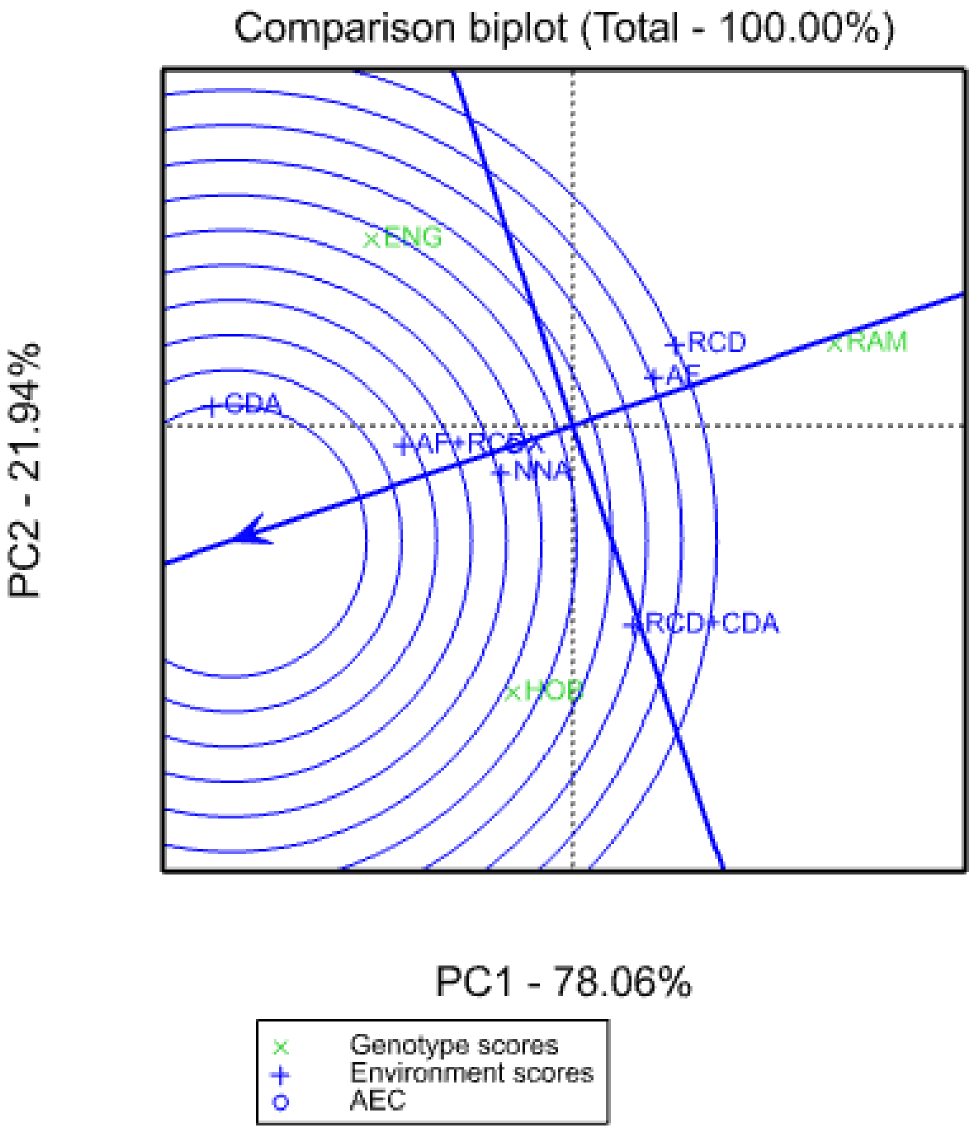

Fig. 3. A Biplot showing genotypic responses evaluated in different soil amendments in summer

HOB, RAM and ENG are rape genotypes. CDA- cow-dung ash, RCD- raw cow-dung, NNA- non-nutrient applied, AF-artificial fertilizer. AEC=average environment coordinates

With regards to delineation of soil amendments, RCD+CDA was the common discriminating soil amendment in terms of genotypic biomass mean response in summer and winter trial as evidenced by the longer environment vector (Figs. 3 and 4). This implies that in rape vegetable breeding, such an amendment (RCD+CDA) can be used in early culling of some undesirable rape genotypes since its only discriminating but not representative [21]. However, we must be quick to mention that this research should be repeated with many genotypes and in the similar season so as to be more certain of its discriminative character.

5. CONCLUSION

Rape genotypes performed relatively better in summer than in winter season. However, rape production in summer is affected by the presence of pests and outbreak of diseases. It is therefore, imperative that farmers are assisted to manage these pests and ultimately maximize profit. With regards to soil amendments, RCD+CDA was the best performing soil amendment in terms of genotypic mean biomass performance on biomass mean responses. RAM was the poorest performer across seasons, implying that ENG and HOD should be recommendable varieties to farmers. In terms of delineation of the soil fertilizer amendments, RCD+CDA was the common discriminating amendment in both summer and winter trials. Hence it can be recommended to be used in screening for rape genotypes in a breeding programme.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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https://www.sdiarticle5.com/review-history/82786