ORIGINAL RESEARCH ARTICLE

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

ABSTRACT

Aims: The objectives of the study were to (i) assess agronomic performance of rape (*Brassica napus*) genotypes under different soil amendments and seasons and (ii) identify the most discriminating soil fertilizer amendment on genotypic responses of rape.
~~**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.~~
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~~Materials and Methods~~: 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 6 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 RCD+CDA 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. RCD+CDA was the common discriminating amendment in both summer and winter trials

***Key-words:** Rape, Soil fertilizer amendment, Nutrient content, Biplot, Summer, Winter.*

1. INTRODUCTION

Rape (*Brassica napus*) is a leaf vegetable which belongs to the *Brassicaceae* family. It is an important source of nutrients 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 places of the country. Generally the quality and quantity of biomass is what influences pricing. Other agronomic trait factors play little or no role on the cost of rape. In Zambia it ranks second from Tomato (*Lycoperscum esculatum*) in providing income among small scale farmers on vegetable crops. [4]
Rape can grow in a wide range of temperature, ranging from0 ^{0}C to 29 ^{0}C. However, the optimum growing temperature range is between 15 ^{0}C and 22 ^{0}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 [9]. The removal of crop residues from the fields, coupled with low rates of macro-nutrient applications, has contributed to low nutrient levels in the

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soil [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 in rape exists. 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*) 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) but 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 experimental site was chosen near an artificially dug well to ensure the crops were water stress free. 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.

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^{o}C	04^{o}C
Maximum temperature	39^{o}C	25^{o}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).pH=degree of acidity and alkalinity of a substance, UV=ultra-violet, AM=after midnight, PM=past midnight.

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 was 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 and 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 30cm spacing within row and 30 cm between rows.

2.2.1 Chemical composition of the applied soil amendments

The chemical composition of the soil amendments samples were evaluated at the University of Zambia, School of Agricultural Sciences and the results are shown in Table 2.

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 and cow-dung ash, CDA- cow-dung ash, AF+RCD+CDA- artificial fertilizer, raw cow-dung and cow-dung ash. Amend- Soil fertilizer Amendment. pH- potential of hydrogen (degree of acidity/alkalinity of a substance). N- Nitrogen, P- Phosphorus, K- Potassium, Na- Sodium, Ca- Calcium, Mg- Magnesium, *

2.2.2 Application Rates of Applied Soil Amendments

RCD and 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 20:20:1. 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 (8) of plants involved.

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 (8) plant from individual unit plots were harvest 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 (18th 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 significant 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 significant differences in genotypic and soil amendment main effects responses on all measured parameters except for height.

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

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)

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.

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.

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)

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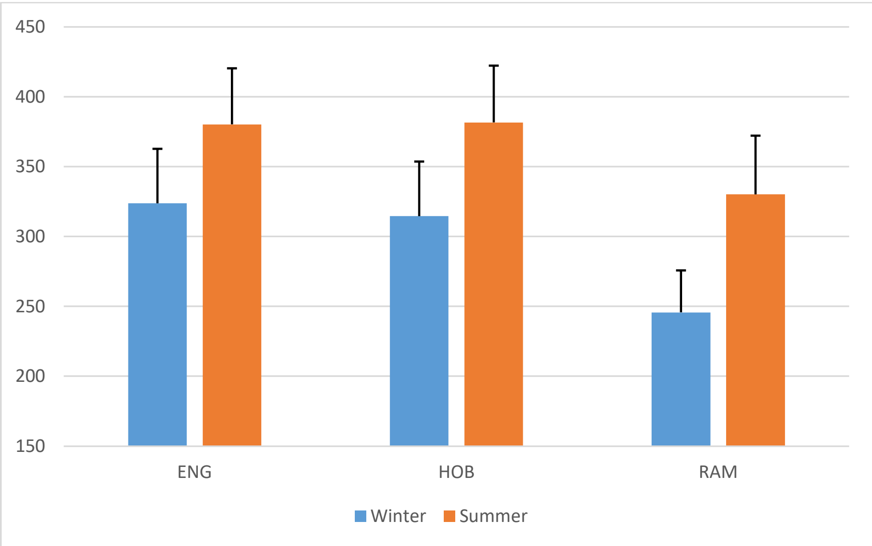

Fig.~~ure~~ 1. Response of biomass to interaction of ‘Genotype x Season’ across soil amendments. ENG=English giant rape, HOB=Hobson rape, RAM=Rampart rape Bars- Error bars

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

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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). CDA was identified as a representative amendment, as evidenced by a smaller angle between location vector and the average environmental coordinate (AEC). HOB performed better in RCD+CDA. ENG 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.

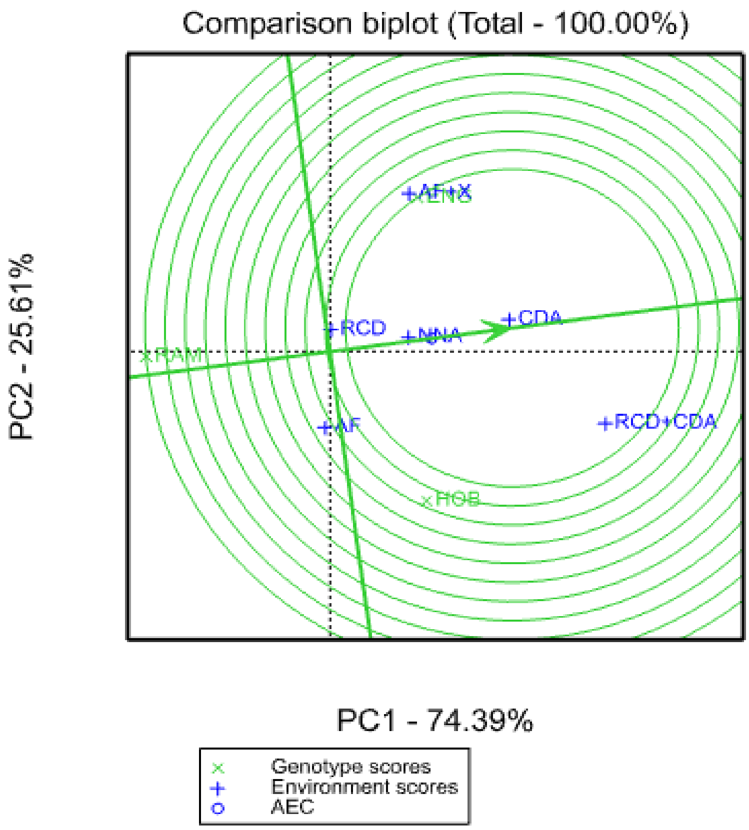

Fig.~~ure~~ 2. Biplot showing delineation of soil amendments with regards to biomass in winter. CDA-cow-dung ash, RCD- raw cow-dung, NNA- non-nutrient applied, AF-artificial fertilizer, AF + X - AF+RCD+CDA. HOB, RAM and ENG are rape genotypes Genotype-Green cross symbol, Environments- Blue plus symbol

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

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). 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.

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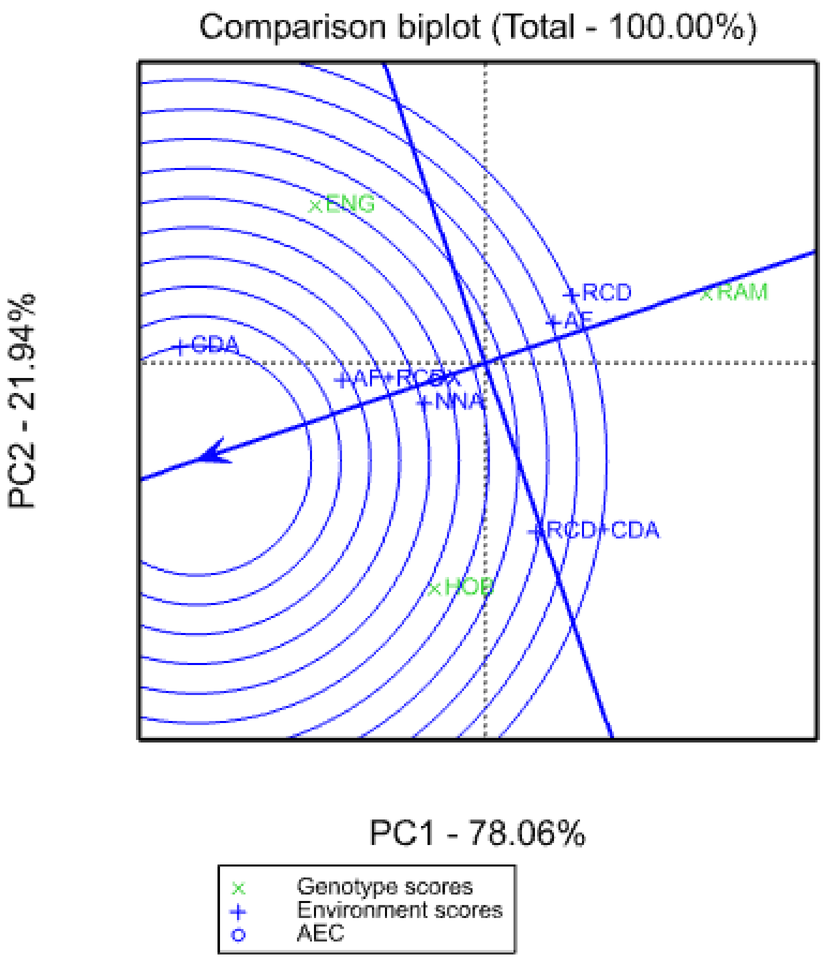

Fig.~~ure~~ 3. A Biplot showing genotypic responses evaluated in different soil amendments in summer. HOB, RAM and ENG are rape genotypes. CDA- cow-dung ash, RCD- raw cow-dung, NNA- non-nutrient applied, AF-artificial fertilizer. AEC=average environment coordinates.

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 a 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].

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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]. The presence of micro-organisms and their activities also depend on alkalinity and acidity concentration in the soil [19]

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 (Fig. 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 [**20**]. 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 English giant rape, Hobson rape should be recommended 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.

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COMPETING INTERESTS ~~DISCLAIMER~~:

Authors have declared that no competing interests exist. 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.

AUTHORS' CONTRIBUTIONS

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