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Effect of haricot bean varieties (*Phaseolus vulgaris*)- Camelina (*Camelina sativa* L) intercropping on yield and yield component over monocropping system of Hosanna, Ethiopia

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Abstract

Cereals-haricot bean intercropping is one of the commonly practiced agronomic practices in Ethiopia. Intercropping is the production of two or more crops simultaneously in both space and time. Field experiments were conducted at Wachemo University main campus experimental field site, from June to October during the years 2022 cropping seasons. The aim of the study was to determine optimum space of intercropping haricot bean into the camelina cropping system under field condition. The experiment was laid out in completely randomize block design with combination of four haricot bean varieties, Local, Nesser, Redwolita and Ibado from Hawassa agriculture center and the four types of spacing for camelina were mono cropping, 40, 60, and 80cm spacing was used as a factor. Soil physico chemical analysis indicated that there was variation before planting and crop harvest. Planting haricot bean simultaneously all among spacing and mono cropping, and camelina was intercropped with haricot bean in the mentioned spacing. Intercropping was assessed on the basis of the performance of the main and component crops indices as grain yield, biomass weight, partial and total LER and competitive indices such as relative crowding coefficient (K), aggressively (A). There was no interaction between camelina and haricot bean varieties planting and spacing intercropping haricot bean in any of the indices studied. The effects of intercropping practice had no significant effects on all the indices considered during the study. But better yield parameters like number of branches, number of pods per pod, number of seeds per pod grain yield, tended to be higher in the Ibado variety and Red wolyta with spacin of camelina 60 and 80 c respectively. The results obtained showed that the greatest intercrop yields of camelina and haricot bean were obtained when both crops were planted at mono. The total land equivalent ratio (LERt) values were not obtained from intercropping of planting of camelina and haricot bean. The results of competitive indices indicate that camelina was the dominant crop in the mixture as measured by the positive values of A. in general as camelina is new emerging crop in the study area and intercropping with legume plants increased yield so that to come with sounding conclusion and recommendation similat works with different agro ecology and years should be done.

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Introduction

The improvement of crop productivity is the common aim of farmers and agriculturists in all with full production packages. Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Gomez and Gomez, 1983). Intercropping, double cropping and other mixed cropping practices that allow more efficient uses of on farm resources are among the agricultural practices associated with sustainable crop production (NRC, 1993; Tolera, 2003).

Intercropping provides year-round ground cover, or at least for a longer period than monocultures, in order to protect the soil from desiccation and erosion. By growing more than one crop at a time in the same field, farmers maximize water use efficiency, maintain soil fertility, and minimize soil erosion, which are the serious. Draw backs of mono-cropping (Hoshikawa, 1991). It also reduces seasonal work peaks as a result of the different planting and harvesting times of intercropping crops. Moreover, it could serve to increase output per unit area, particularly with low levels of external inputs since a mix of species makes better use of available nutrients and water in the soil (Kotschi *et al.*, 1986).

Numerous researchers cover the theory and mechanisms of yield stability in intercropping. Willey (1979a) clearly and evidently proposed that intercropping gives higher yields in a given season and greater stability of yields in different seasons compared with sole cropping. Moreover, Mead and Willey (1980) stated in detail that in intercropping systems, yields are more stable. Its relation to yield stability is the notion of risk, in terms of either productivity or income or both. Beets (1982) thought that crop insurance was a major principle of intercropping in that if environmental factors change, some of the intercrop does well when others do poorly. He thought that for intercropping to be risk advantageous, the components of the crop association needed to have different environmental requirements or contrasting habits. Clawson (1985) concluded that traditional farmers cultivate a great variety of crops in order to maximize harvest security. This included intra species diversity such as different colors of maize with different maturation times. Wolfe (1985) reported that grain mixtures can generally provide a better guarantee of high yield than a priori choice of a single best variety, largely due to the un predictability of the growing season.

For most poly culturist production goal is income; just as productivity is determined by environment of ecological and technical factors; income is governed by a wide array of psychological, cultural, input, costs and market factors (Geno and Geno, 2001); polyculturaliests, seeking both subsistence and market income make clear and repeated choices to avoid risk and income variability. Besides the benefit of yield and income, intercropping can be seen to produce social benefits to both the land-holder and the surrounding community (Geno and Geno, 2001). Bradfield (1986) noted that updating traditional intercropping practices (as opposed to promoting monocultures) offers the potential of scale specific technologies that favor the small farmer. Addressing the question of equity, Willey (1981) found that the advantages of multiple cropping, that the benefits are achieved not by means of costly inputs but by the simple suitability of growing crops together. Thus intercropping offers a very genuine way in which the poorer or smaller farmer can benefit at least as much as the better return one. Similarly, Jodha (1981) noted that research reveals its potential for greater employment. Because intercropping is often a system used on small farms, any breakthrough in intercropping technology will help poor farmers more than the rich, thus better serving equity.

The key to sustainable agriculture probably lies in increased output per unit area together with arable land expansion. However, the recent demographic pressure has forced agricultural planners and development agencies to review the role of multiple cropping as a means to enhance agricultural production, since the extent of suitable agricultural land is static or diminishing (Midmore, 1993). In terms of cropping systems, the solutions may not only involve the mechanized rotational mono-culture cropping systems used in developed countries but also the poly-culture cropping system traditionally used in developing countries (Tsubo *et al.*, 2003).

The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labour more efficiently (Baldy and Stigter, 1997). Biophysical reasons include better utilization of environmental factors, greater yield stability in variable environments and soil conservation practices. Socio-economic reasons include the magnitude of inputs and outputs and their contribution to the stabilization of household food supply (Beets, 1982).

Potato-beans-maize and sweet potato-maize have all been shown to be 1.5-2.8 times more productive than the sum of the individual monocultures (Rosset, 1997). Cereals can be intercropped with most vegetables such as tomato, beetroot, carrot, celery, potatoes, radish, strawberries, and leeks (David, 1998). For example, Gebru *et al.* (2015) reported that the highest LER, GMV and MA values of 2.06, 171077.73 Eth. Birr/ha (≈ 10063.40 US$/ha) and 88030.29 Eth. Birr/ha (≈ 5178.25 US$/ha), respectively, were recorded from the 100T:50M combinations, where maize was intercropped haricot bean. Thus, intercropping is an optional cropping system and that plays a significant role in securing of food for a nation.

Due to lack of recommendations on spacing of oil crop camelina with nitrogen fixing legume (haricot bean) on farmers' fields appears lower or higher than the optimum, as a result very low yield is obtained. In addition to this seeds sown broadcast seeding is distributed unevenly (which may result in overcrowding). Also this method may not ensure that all seeds are sown at the correct depth for nutrient competition and fixation. Furthermore, in haricot bean varieties intercropping with oil seed camelina is nil as a whole in country level. Therefore, it is of paramount importance to identify the type of varieties and oil seed camelina intercropping which yield more, and also derive larger part of their N fixation in a particular cropping system.

Objectives

General objective

❖ To increase the production camelina-haricot bean varieties intercropping through identification and use of optimum spacing

Specific objectives

❖ To identify optimum spacing of haricot bean varieties and camelina that result in increased growth and yield components

❖ To identify haricot bean varieties that respond to spacing with camelina crop.

❖ To investigate if there are interactions between camelina crop and haricot bean varieties.

Materials and methods

Description of area

The experiment was conducted at Wachemo University farm experimental site during 2021 cropping season. Wachamo University found 222 km away from Addis Ababa which is the capital city of Ethiopia and 198 km from Hawassa which is the capital city of south nations, Nationalities of the people. It lays an altitude of 1500-2300 Masl. The location with 7°14' to 7° 45' North latitude and 37° 5' to 37° 50' East Longitude, representing a high altitude and high rain fall environment. The area receives a mean annual rain fall of 1800mm with mean maximum temperature of 16-24°c and minimum of 16°c. The soil is clay loam with Ph of 5.8.

Factors of the experiment

Treatments, Experimental Designs and Procedures the experimental design will be Factorial Experimental Design by Using RCBD with four types of haricot bean varieties (Variety local, variety 2 Nesser, variety 3 Ibabo and variety 4 Red wolayta) and three types of population density with three replications.

The following tabel 1. treatments was get from the combination of these two factors:

1. Mono cropping of Varity 1
2. Mono cropping of camelina
3. 40cm intercropping with Varity 1
4. 60cm intercropping with Varity 1
5. 80cm intercropping with Varity 1

6. Mono cropping of Varity 2
7. Mono cropping of camelina
8. 40cm intercropping with Varity 2
9. 60cm intercropping with Varity 2
10. 80cm intercropping with Varity 2
11. Mono cropping of Varity 3
12. Mono cropping of camelina
13. 40cm intercropping with Varity 3
14. 60cm intercropping with Varity 3
15. 80cm intercropping with Varity 3
16. Mono cropping of Varity 4
17. Mono cropping of camelina
18. 40cm intercropping with Varity 4
19. 60cm intercropping with Varity 4
20. 80cm intercropping with Varity 4

Field Layout

Factorial Experimental Design by Using RCBD

The field was oxen plough..o 3 times before sowing. The seed sown directly in rows depending on treatment and 5cm between plants. Three seeds per hill was planted in each row and thinned to a single plant per hill after two weeks of germination to maintain the plant population in each treatment. Phosphorous will be applied equally for all treatments applied at sowing as urea (46% P).

A 3.2 m x 2.5 m plot size was used as an experimental unit, there is 1m distance between in each plots. The blocks will be separated by a 1 m wide space and the total experimental area will be 528 m^2 (61.4m × 8.6m). Each treatment will be randomly assigned to the experimental unit within a block.

Data to be collected

Agronomic data and Phonological parameters

1. Days to 50% emergence from each variety was recorded

2. Days to 50% flowering were determined as the number of days after seedling emergence to the period when 50% of the plants in a plot develop first flower.

3.Days to 90% maturity was taken as the number of days after seedling emergence to the period when 90% of the plants in a plot will ready for harvest as revealed by change in the foliage and pod color and seed hardening in the pods.

Yield and Yield Components

The following parameters were recorded from the central four rows of each plot:

1. Seed yield will be measure from the air-dried seeds of the net plot area and adjusted at 12.5% seed moisture content for both camelina and haericot bea varieties.

2. Biological yield will be determined by drying the above ground biomass in an open air (including the seed yield) for both camelina and haericot bea varieties.

3. Number of primary branches will be determined by counting the number of primary branches from the main stem of three randomly selected plants per plot.

4. Number of secondary branches will be determined by counting the number of secondary branches extended from primary branches of the main stem from three randomly selected plants in the net plot at maturity.

5. Plant height will be measured at 50% flowering and physiological maturity by measuring the main stem height from the ground to the canopy height using a ruler from randomly selected five plants per plot for both camelina and haericot bea varieties.

6. Number of pods per plant was be recorded from eight randomly selected plants from the net plot area at harvest for both camelina and haericot bea varieties.

7. Number of seeds per pod was determined from randomly selected five pods from the plot area at harvest for both camelina and haericot bea varieties.

8. Number of seeds per plant was determined by multiplying the number of pods per plant and number of seeds per pod for both camelina and haericot bean varieties.

9. Leaf area will be determined by measuring the area of leaves from top, middle and lower part of three plants selected from each plots using CI-202 ortable area meter.

Land Equivalent Ratio

(LER) is the most commonly used to indicate the biological efficiency and yield per unit area of land as compared to mono-cropping system; an LER greater than 1.0 implies that for that particular crop combination, intercropping yielded more than growing the same number of stands of each crop as sole crops.

Actual time Equivalent Ratio

ATER also provides more realistic comparison of the yield advantage of intercropping over mono-cropping in terms of time taken by component crops in the intercropping systems.

Competitive ratio

CR gives better measure of competitive ability of the crops and is also advantageous as an index over K and A (Willey and Rao, 1980). The CR simply represents the ratio of individual LERs of the component crops and takes into account the proportion of the crops in which CR tomato (LER tomato/LER intercrops) (Zba/Zab) CR intercrops= (LER intercrops/LER tomato) (Zab/Zba)

Soil sampling analysis

Surface soil samples (0 to 30cm) will be collected before sowing from 20 spots and composited and analyzed in the laboratory for selected chemical and physical soil properties. The soil samples will be air dried and passed through a 2mm mesh sieve for physico-chemical analysis. Soil texture determination will be done by Bouyoucos hydrometric method. Organic matter is also determined based on the oxidation of organic carbon with acid dichromate medium following the Walkley and Black method will be used to determine total N. Soil Cation Exchange Capacity (CEC) is determined by NH4- AOC method (Page, 1982). The available soil P will be determined According to the methods of Olsen and Dean (1965). Soil pH is also determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital pH meter.

Analysis of productivity and benefit

Among different methods used to indicate a yield advantage of intercropping Land Equivalent Ratio (LER) was used to indicate the biological efficiency and yield per unit area of land as compared to the sole-cropping system. The LER values were computed by using the formula described

LER = Ymi /Yms + Yhbi /Yhbs

Where, LER=land equivalent ratio, Ymi=yield of camelina in intercrop, Yhbi=yield of haricot bean in intercrop, Yms=yield of camelina sole, Yhbs=yield of haricot bean sole

LER>1.0 implies, intercropping yielded more than growing sole cropping.

LER<1.0 implies, intercropping yielded less than sole cropping

LER=1.0 implies, there is no different yield advantage between sole and inter-cropping

Data Analysis

Data collected was subjected to Analysis of Variance (ANOVA) using SAS Software appropriate to the design of the experiment. Mean separations will done LSD as cited in Gomez and Gomez (1984). ANOVA will be considered to test for significant differences among treatment means. Economic yield data will be transformed (arcsine of the square root) prior to ANOVA. The 5% level of probability ($p < 0.05$) will be used in all statistical tests.

Result and discussion

Physico-chemical analysis of experimental site

Soil analysis before planting

The laboratory analyses were conducted, Wolikete soil laboratory) on soil samples collected before planting and after crop harvesting. The analytical results indicated that the textural class of the experimental site soil was clay loam with a proportion of 40.2% clay, 28.5% silt and 31% sand and after crop harvest the proportion is 40.1% clay, 28.7% silt and 31.2%.

According to Olsen *et al. (*1954) soils can be classified based on their available P contents, with ranges of <5, 5-15, 15-25 and >25 mg kg^{-1} as very low, low, medium and high, respectively. Thus, with respect to available P, the experimental soil rated in high range (>25 mg kg^{-1}). Havlin (1999) indicated that soils having total N contents with ranges of <0.1, 0.1- 0.15, 0.15-0.25, 0.25- 0.5 and >0.5% can be grouped as very low, low, medium, high and very high, respectively. Thus, with respect to total available N, the soils of the experimental area can be rated in a low range (Table 2). Most Ethiopian soils, similar to the agricultural soils in other tropical countries, are reported to be generally low in N (Asegelil, 2000). In view of the low level of N in soils and the limitation for crop production, in general, application of legume seeds with p fertilizer N fixation and contribute to the replenishment of soil N for better yield in crops. According to Jackson (1958) and Herrera (2005), soil carbon content rated as into very low (< 2%), low (2-4), medium (4-10), high (10-20) and very high (>20%), thus the soil at experimental site has very low carbon content.

Table 2. Selected physico- chemical properties of the experimental soil before planting.

Physical properties				Chemical properties		
Particle size distribution (%)			Textural class	pH:1.25 H_2o	Total soil N (%)	Available p mg/kg
Sand	Silt	clay	Clay loam	5.4	0.32	46
31.5	28.5	40.	23			

TN=total nitrogen in the soil, OC=organic carbon in the soil, Av.P=available phosphorous in soil

Physical properties after				Chemical properties after		
Particle size distribution (%)			Textural class	pH:1.25 H_2o	Total soil N (%)	Available p mg/kg
Sand	Silt	clay	Sandy loam	5.8	0.420	46.3
31.2	26	40.1	28.7			

Effect of intercropping and seeding rate on phonological growth

Effect on days emergence and flowering

The intercropping or spacing tested has no significant variation with respect to days of 50% emergence but there was variation on days of 50% flowering Paldh (2004) reported that seed size, sowing depth, land preparation and environment influence the germination and emergence of the seedlings. Aikins and Afuakwa (2008) indicated that uniform and complete emergence of vigorous seedlings positively affect the overall output of an annual crop by allowing the establishment of better canopy structure and providing time and spatial advantages to compete with weeds. There was significant variation among phosphorus with respect to days of 50% flowering.

Similarly, also there was a significant difference on days to 50% flowering among haricot bean varieties, maximum number of days recorded on Ibado variety but the others took similar days and there was also a significant variation on varieties.

Days to flowering

Days to 50% flowering differed significantly between spacing shown in Table 3. 60cm, had the highest recorded to days of flowering (95) for camilina 102 for Ibado variety, thus indicating that it will have more duration for photosynthetic production and dry matter accumulation. It may have an increased capacity to exploit the soil.

Number of branches per plant

The number of branches per plant was found to be statistically significant ($P < 0.05$) affected by intercropping camelina with haricot bean verities and higher number of branches obtained by both case sole cropping this might be due moisture and nutrient competition is very low in sole cropping. This work disproves works of Dunn *et al.* (1999) Water use efficiency is also another importance of intercropping system. Suggested greater water resource capture was essential to solving environmental water leakage. Some studies says that intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components. For example, tomato intercropped with grain sorghum as the shade crop yielded more than pure stand tomato with little loss of sorghum yield and the Land Equivalent Ratio of the tomato + sorghum intercrop ranged from 2.58 to 2.99 (Kamel *et al.*, 2004).

Number of pods per plants in camelina and haricot bean varieties

The number of pods per plant was found to be statistically significant ($P < 0.05$) affected by different intercropping and varieties in different spacing. Specially, Ibado varies with camelina intercropped has significant had higher number of pods. Nessar with and 80cm wit camelina had resulted significantly higher number of pods per plant whereas effect of applications of local variety and 40cm camelina were statistically at par. Intercropping was significantly different (p< 0.0S) with respect to number of pods per plan almost all in intercropping the higher the spacing the better the pods in both crops this might be due to nutrient and moisture compaction is low but the potential of haricoat bean for atmospheric nitrogen fixation good in soil analysis this might add some branching tillers to survive.

The works of Willey (1979a) supports our work thought that light was the most important factor and noted that it was different from other growth resources in that it is only instantaneously available and thus must be instantaneously intercepted to be of benefit while other resources are typically pools awaiting plant exploitation and in our case Ibado variety has higher leaf expansion that might affect the intropcropped camelina for light completion.

Effects of intercropping and Haricot bean varieties on physiological maturity

In cropping with differed spacing of camelina and four types of haricot bean varieties had significantly affected physiological maturity (at P< 0.05) (Table 3), where, all haricot bean varieties took the highest days while local verities were the least. And also intercropping camilina with different spacing differs significantly with respect to physiological maturity. Studies by (Willey, 1990) improved maturity and productivity can result from either greater interception of solar radiation, higher light use efficiency, or a combination of the two. As shown in Table 3, the interaction effect of intercropping camelina with haricot bean varieties almost I all components were not significantly differed (at P< 0.05)

Table 3. Effects of Camelina haricot bean intercropping on phenology and yield parameters.

Treatments	space	50% emergence	50% flowering	Branches per plant	Days to maturity	Pod per plant	Seeds per pod	Yield kuntal per ha.
Camelina	mono	7.5	97.4	7.8^{B}	109.5^{B}	195^{B}	11^{B}	28.99^{B}
	40	7.54	98.8	7.84^{B}	105.5B^{A}	198^{BA}	11.5^{BA}	29.59^{BA}
	60	7.55	99.33	8.1^{BA}	117^{A}	198.4^{BA}	11.7^{A}	29.76^{BA}
	80	7.54	99	8.5^{A}	117.5^{A}	201^{A}	11.9^{A}	29.9^{A}
LSD (5%)		NS	NS	0.37	1.9	4.6	0.7	0.77
Haricot beanVariety	Mono	8.4^{B}	102^{B}	4.9^{CB}	120^{C}	22^{B}	6^{B}	30.9^{C}
	Local	8.5^{B}	99^{B}	6.6^{A}	123^{B}	25^{A}	4.3^{BA}	28.25^{C}
	Nessr	9.3^{B}	100^{BA}	5.0^{A}	123^{B}	24^{A}	5.8^{A}	30^{B}
	Ibado	9.1^{A}	$113.^{A}$	6.6^{A}	128.7^{A}	29^{A}	6.8^{A}	35^{A}
LSD (5%)		0.45	4.0	2.3	1.9	8.6	3.1	2.2
CV%		3.7	4.3	5.5	2.14	2.7	7.2	3.14
Spacing * Varieties		Ns	ns	ns	ns	ns	ns	ns

Mean values within column followed by the same letter are not significantly different (p≤ 0.05), NS = non-significant at 5% probability level, n=48(Number of observation for each parameter) *, ***, **=Significant at 5%, 1% and 0.1% probability

Effects of intercropping camelina and Haricot bean varieties on grain yield

The effects of different intercropping of camelina and haricoat bean varieties on the grain yield are shown in Table 3. Grain yield differed significantly haricoat bean varietal, and the highest seed yield was obtained in Ibado (2.99 t ha^{-1}). Similarly, the lowest obtained in Nesse variet and in this case local or farmer cultivar was even more than Nesser. Intercropping Ibado with camelina at 60 c spacing is very high yielded. This agrees with the works of Carandang (1980) thought that intercrops allow maximum utilization of sunlight by increasing light interception by 30-40%. Other works also investigated that Pino *et al.* (1994), yield advantage of intercropping is also common to reduce pests of crops.

Land equivalent ratio (LER)

The land equivalent ratio (LER) is the relative area of a sole crop required to produce the yield achieved in intercropping. The analysis of the result showed that, partial land equivalent ratio of camelina was less than one for all arrangements in the treatment. LER value is equal to one, it means that there is no yield advantage, but when LER is nearly equal one, and then there is a yield good with considering the nitrogen fixation value from atmosphere which supplies urea fertilizer. For camellia was more than 0.5, it indicated disadvantage for in inter-cropping.

The highest PLER of camelina 0.60 and was obtained from one to one row of camelina and haricot bean cropping.. The partial land equivalent of camelina increased as the population of haricot bean decreased, this may be due to computation for moisture and nutrients Belstie L, Walelign W, Sheleme B (2016) reported PLER values ranged from 0.86 and 0.93 among different arrangements of haricot bean in maize rows. Adetiloye *et al* (1983). Also reported partial land equivalent ratio ranged from 0.83 to 0.87 in his study of advantages of maize-haricot bean inter-cropping over sole cropping of maize.

Conclusion and recommendation

Southern Ethiopia crop productivity is the common aim of farmers and agriculturists in all with full production packages. Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to nutrient and moisture use efficiency Therefore, this research was conducted during the 2021 main cropping season in Hadiya area Wachemo University farm experimental center to investigate the effect of haricot bean varieties (*Phaseolus vulgaris*)- Camelina (*Camelina sativa L*) intercropping on yield and yield component over mon-ocropping. The experiment was comprised of 16 treatments made up of a factorial combination of two input factors [four types of spacing (mono, 40, 60 and 80cm) and and four types of varieties, (Local, Nesser, Redwolyta and Ibado). The experimental design was RCBD with three replications and 16 treatment combinations. Results obtained from the experiment indicated that most of the parameters tested significantly responded ($p < 0.05$) to the treatments. For growth parameters and yield components, 60 and 80cm spacing wth Ibado showed significant differences grain yield. In the case of yield and yield components camelina intercropped with Ibado and Red wolta had higher performance over mono cropping. Haricot bean mono cropping showed significant effects on all parameters of yield and yield components and in almost all cases rate except Nesser. The present study demonstrated that, intercropping could improve camelina yield but the land equivalent ratio showed there were no yield variation almost in all varieties except Ibado. However, so far, researches on the contribution of intercropping in the he farming system are given lower emphasis, as compared to mono-cropping and sole cropping and their adoption awareness for camelina is to less. This study also has shown the potential contributions of camelina intercropping to haricot bean and the nitrogen input costs of camelina was reduced. Investigations on other agronomic like intercropping practices which give an appropriate consideration to growth under various locations should also be done. Finally, the present study should be further evaluated under various agro ecological conditions in order to come up with conclusive recommendations to be used by small holder farmers.

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