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Growth and Yield of Sorghum as Influenced by Population Density and Time of Introduction of Component Cowpea

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Abstract
A field trial was carried out at the Teaching and Research Farm of Kwara State University, Malete, Nigeria during 2018 cropping season to investigate the productivity and competitive behaviour as influenced by population density and time of introduction in sorghum/cowpea intercropping. Full population density of sorghum was combined with four population densities of cowpea (100S:100C, 100S: 75C, 100S: 50C and 100S: 25C where S and C represented sorghum and cowpea, respectively) at three period of introduction of cowpea (same time, two weeks after, and four weeks after planting). The treatments were arranged as 3 x 4 factorial combinations in split plot and replicated three times. Sole crop of both cowpea and sorghum were included in the treatment as a check. The number of branches of cowpea was found to decrease with the delayed in the time of introduction. The least grain yield of sorghum (1,160.84 kg/ha) and cowpea (583.38 kg/ha), respectively were recorded at 100S:100C and 100S:25C population ratios. The yield of sorghum increased with delayed in the time of introduction of cowpea irrespective of population ratio. The grain yield of cowpea reduced as the population density reduced and with further delayed in the time of introduction. The land equivalent ratio (LER)and land equivalent coefficient (LEC) demonstrated intercropping advantages at all population ratios tested when the two crops were simultaneously planted with the highest values, 1.23 and 0.38 for LER and LEC, respectively obtained at 100S: 75C population ratio. Regardless of population ratios and time of introduction, the aggressivity value was positive for sorghum and negative for cowpea and increased as the population of cowpea decreased and with delayed in the time of introduction of cowpea. Simultaneous planting of sorghum at full population with 75% population of cowpea was found better compared to other treatments and hence, recommended for adoption in sorghum/cowpea intercrop.

Keywords: Sorghum, cowpea, population ratios, aggressivity, LER, MAI

Introduction
Plant population and time of introducing the component crops among others are important factors for consideration if maximum productivity is to be achieved in crop mixtures. This is because the number of plants per unit area will create a micro-environment that could influence the growth, development and yield in any cultivated crops. According to Caliskan *et al.* (2007) within certain limits, increased plant population decreased the growth but the reverse occurred for yield per unit area. Similarly, Rahman and Hossain. (2011) reported that increased plant density in soybean decreased yield components such as number of pods per plant, seed per pods, 100 seed weight as well as seed yield.

The period of planting is an important factor for consideration for successful intercropping advantage. Crops with wide maturity dates may be simultaneously planted with a view to safeguard crop failures particularly areas with unstable rainfall and also to reduce competition among component crops. Planting may also be staggered to increase the temporal differences to achieve higher yield advantages (Singh and Ajeigbe, 2002). Complementarity in an intercrop can occur when the growth pattern of the component crops differs in time or when they make use of resources in space. Studies have shown that the effect of competition between component crops is reduced when their maximum demand for natural resources occur at different time (Afe and Olofintoye, 2013).

Intercropping cereal with legume is popular in the tropical farming system (Hauggard-Nielson *et al.*, 2001) as well as the rain fed areas of the world (Banik *et al.*, 2000) due to various advantages associated with the system (Agegnehu *et al.*, 2006). For instance, intercropping legumes with

cereals increases the availability of other nutrients including phosphorous (Xia *et al.* 2013, Crème *et al.,* 2016) and also increases soil microbial population (Wahbi *et al.,* 2016). Sorghum-cowpea intercropping is an important farming system for small scale farmers in Arid and Semi-Arid Lands of sub-Saharan Africa. Intercropping sorghum with groundnut was reported to significantly reduce the yield of sorghum (Langa *et al.* 2006). In another study, Oseni and Aliyu (2010) obtained a reduction of 69.7% in sorghum yield in sorghum/cowpea intercropping. Kunde *et al.* (2015) reported that intercropping cowpea with sorghum depressed sorghum yield. In the study, simultaneous planting was found better compared to other planting periods. Similarly, Gandebe *et al.* (2010) suggested simultaneous planting in cowpea maize mixture to enhance cowpea yield because the time of introducing cowpea into maize was found to significantly affect the yield of cowpea. Karanja *et al.* (2014) obtained lowest grain yields of both cowpea and sorghum at the highest intercrop population (1000S:100C). According to the study, increased cowpea intercrop population from 55,555 to 166,666 plants/ha significantly influenced crop growth, grain yield attributes of both crops.

The unstable rainfall in the recent time due to climate change with attendant decreased in the crop yield has necessitated the need for research in intercropping involving cowpea and sorghum since the two crops are moderately resistant to drought with a view of increasing productivity and safeguard crop failure. According to Kour *et al.* (2013), intercropping has the potential to improve the overall productivity through efficient and complementary use of water. On this premise, hardy crops for sustainable food security was advocated (Poulton and Kayinga, 2014) as a means of increasing productivity in an area prone to unstable rainfall. Ouda *et al.* (2007) opined that the advantages of intercropping has not been fully exploited by rural farmers as a means of improving productivity especially under water-limited conditions.

Traditionally, in Nigeria, sorghum being naturally resistant to drought is planted in June/July depending on the cultivar and matured in November/December. Kumar *et al.* (2011) opined that legume were naturally adapted to dry tropical condition. With several studies in cereal legume mixture, identifying the population density of cowpea and the suitable time of introduction as well as their competitive behaviour for optimum productivity have not been reported. This study was therefore designed to investigate the population density of cowpea suitable for intercropping with sorghum, the appropriate time of introduction as well as competitive behaviour for optimum productivity in sorghum-cowpea intercropping.

Materials and Methods

Study location.

The field trial was carried out at the Teaching and Research Farm of Kwara State University, Malete in the Southern Guinea Savannah Ecological Zone of Nigeria during 2018 cropping season.

Planting Materials

The sorghum cultivar CRS-01 and cowpea Vital-5 used for the trial were respectively obtained from National Cereal Research Institute, Badeji, Niger State, Nigeria and an agro outlet at Ilorin, Kwara State, Nigeria.

Experimental Design

Full population density of sorghum was combined with four population densities of cowpea (100S:100C, 100S: 75C, 100S: 50C and 100S: 25C where S and C represented sorghum and cowpea, respectively) at three period of introduction of cowpea (same time, two weeks after, and four weeks after planting).The treatments were arranged as 3 x 4 factorial combinations in split plot design and replicated three times. Sole crop of both cowpea and sorghum were included in the treatments as a check. The period of introduction constituted the main plots while the population density was assigned to the sub-plot treatments.

Cultural Practices

Planting

Sorghum was planted on the 4th of July, 2018, simultaneously with the first planting of cowpea. The second and third planting of cowpea were introduced to sorghum at two and four weeks after planting, respectively in a single alternate row arrangement with five rows each of sorghum and cowpea.

Fertilizer Application

NPK 20:10:10 was applied to sorghum at the rate of 300 kg/ha at four weeks after planting. Single super phosphate was applied to cowpea at the rate of 20% P_2O_5/ha at one week after planting

Weed Control

Pendimethalin mixed with paraquat at the rate of 1.5 litre/ha each was applied immediately after the

first planting using knapsack sprayer. This was followed with manual weeding as at when due such that the experimental field was weed-free during the trial.

Harvesting

Sorghum was harvested manually at the two innermost rows by cutting the panicle with a sharp knife. The cut panicles were sundry to reduce the moisture content and thereafter, the panicles were manually threshed to remove the grains and winnowed. Cowpea was also harvested manually at the two innermost rows, threshed and winnowed. The harvested grains of both crops were converted to grain yield per hectare.

Data Collection

Data were collected on the following variables:

a. Sorghum: Plant height at 4, 6, and 8 weeks after planting, number of leaves, leaf area at 6 and 8 (WAP), weight of 100 seeds and grain yield.
b. Cowpea: Number of branches and pods per plant, pod length, number of seeds per pod, weight of 100 seeds and grain yield.

Evaluating intercropping efficiency and competitive behaviour

The efficiency of intercropping, competition and economic benefit were assessed using the Land Equivalent Ratio (LER), land Equivalent Coefficient (LEC), Aggressivity, Competitive Ratio (CR), and Monetary Advantage Index (MAI) indices.

The LER which assessed the biological efficiency of intercropping was calculated as proposed by Willey (1985).

LER= (Yab/Yaa) + (Yba/Ybb),
where Yaa and Ybb are sole yields of crops a and b, and Yab and Ybb are the intercrop yields of crops a and b, respectively. Land Equivalent Ratio (LER) values greater than unity was considered advantageous

The Competitive Ratio (CR) was calculated using the formula proposed by Willey and Rao (1980). The CR describes the degree of competition among component crops in the mixture by measuring the ratios of individual LERs of the two component crops along with the proportion in which they were sown in the mixture. A higher CR value indicates a higher competitive ability.
CR (sorghum) = Ls x Zsc/Lm x Zcs,
CR (cowpea) = Lc x Zcs/Ls x Zsc,
where: Ls and Lm are the partial LER for sorghum and cowpea, respectively;
Zsc and Zcs = proportions of sorghum and cowpea, respectively.
Aggressivity (A)

The value of A was calculated by the formula proposed by McGilchrist (1965). Aggressivity (A is a measure of how much a relative yield increase of one species (dominant) is greater than of the other species (dominated or recessive) in the mixture. The A value for component crops a and b is usually the same, but the dominant crop gives a positive value, while the dominated crop gives a negative value. When the value of A is high it indicates a higher difference between the actual and expected yield.

$$Aab = \frac{Yab _ Yba}{Yaa \times Zab\ Ybb \times Zba}$$

where:
Aab = Aggressivity value for component crop a,
Yab = Intercrop yield of crop a,
Yba = Intercrop yield of crop b,
Zab and Zba = Sown proportions of crops a and b in the intercrop.

The land equivalent coefficient (LEC), a measure of the level of interaction and productive potential at the intercrop, was estimated as proposed by Adetiloye and Ezedima, (1983).
LEC= (Ls x Lm),

Where: Ls and Lm are the partial LER for sorghum and cowpea, respectively. The partial LER is the ratio of the intercrop yield to the sole crop yield.
The Monetary Advantage Index (MAI) was calculated as described by Ghosh (2004). MAI, assesses economic advantage of the mixture.
MAI = (Monetary value of combined intercrops) (LER – 1) / LER.

The economic values of both crops were estimated based on the prevailing market prices of the two crops at Ilorin during 2018 cropping season. Respectively, N150. 00/kg and N80.00/kg were the prices of cowpea and sorghum grains.

Data Analysis

All the data collected were subjected to analysis of variance using DSAASTAT .1.101 version. (2011) statistical package and the treatments were

separated using Duncan's New Multiple Range Test at 5% level of significance.

Results

Growth and Yield of Cowpea and Sorghum

The heights of sorghum and cowpea at 4, 6, and 8 WAP were significantly influenced by population density (Table 1). Irrespective of the time of introduction and population ratios employed, the height of cowpea was not influenced by intercropping, although, it appeared to increase with increased population and decreased with the delayed in the period of introduction, it was not statistically manifested. The least leaf area (266.39 cm) and lowest grain yield of sorghum (1,160.68 kg/ha) at the intercrop were obtained at the intercrop population were full population (100S:100C) ratio of both crops were mixed (Table 2). The highest leaf area of sorghum (442.77 cm) and grain yield (1,456.64 kg/ha) were recorded at the treatment were cowpea was introduced to sorghum at 4wap. The seed weight of sorghum was not influenced by population density and time of introduction.

The significant effect of population density and time of introduction on yield and yield component of cowpea is presented in Table 3. The number of pods produced per plant at sole crop was significantly higher than the intercrop population ratios. At the intercrop population, the highest number of branches per plant was recorded at the component population ratio 100S:25C. The number of branches and pods produced was found to decrease with the delayed in the time of introduction. Cowpea planted at the same time had more pods and branches than those planted at two and four weeks after planting. The pod length, number of seeds produced per plant and weight of 100 seeds of cowpea were not influenced by population density and time of introduction. The grain yield of cowpea obtained at the sole crop population was significantly higher than the intercrop populations' ratios. The highest grain yield (1064.75 kg/ha) at the intercrop was recorded at the component population ratio 100S:75C.

The significant interactive effect of population density and time of introduction on the yield of sorghum and cowpea is presented in Table 4. Regardless of population ratios, the yield of sorghum was found to increase with delayed in the time of introduction of cowpea. Reverse however, was the case with cowpea as yield reduction was recorded with delayed in the time of introduction at different population ratios. Simultaneous planting of sorghum and cowpea did not affect the grain yield of sorghum. The grain yield of sorghum at component population ratio 100S:100C was at par with population ratio 100S:75C irrespective of the time of introduction. The highest grain yield of cowpea at the intercrop was recorded at 100S:75C population ratio at all the time of introduction.

Yield Advantages and Competitive Behaviour

The yield advantages and competitive behaviour of intercropping sorghum with cowpea at different time of introduction is presented in Table 5. The LER and LEC demonstrated intercropping advantages at all population ratios tested when the two crops were simultaneously planted with the highest values, 1.23 and 0.38 for LEC and LEC, respectively obtained at 100S: 75C population ratio. Introducing cowpea to sorghum at two weeks after planting showed intercropping advantage at component population ratios 100S:100C and 100S:75C. There was no meaningful intercropping advantage when cowpea was introduced to sorghum at 4 WAP. In fact, introducing cowpea to sorghum at 4 WAP as measured by LEC index was disadvantageous. Regardless of population ratios and time of introduction, the aggressivity value was positive for sorghum and negative for cowpea and increased as the population of cowpea decreased and with delayed in the time of introduction of cowpea. The CR followed similar trend with A, it was high for sorghum and increased as the population of component cowpea decreased for simultaneous planting and when cowpea was introduced at 2 WAP. Except component population ratio 100S:25C, the MAI values was positive for all population ratios when the two crops were simultaneously sown and when cowpea was introduced to sorghum at two weeks after planting. Negative MAI values were recorded at 100S:100C and 100S:25C population ratios when cowpea was introduced to sorghum at four weeks after planting.

Table 1: The effect of population density and time of introduction on height of sorghum and cowpea at 4, 6, and 8 weeks after planting (WAP)

Population ratios (PR)	Plant height					
	4 WAP		6 WAP		8 WAP	
S : C	S	C	S	C	S	C
100 : 100	27.57b	18.94	57.68a	24.62a	97.16a	30.83a
100 : 75	29.33a	18.76	56.31a	24.74a	98.80a	31.84a
100 : 50	27.20b	18.74	55.14a	24.78a	94.09a	31.77a
100 : 25	29.29a	18.91	59.13a	24.76a	98.96a	32.22a

100 : 00	27.72ab	-	49.49b	-	94.7aa	-
00 : 100	-	19.14	-	23.31a	-	24.44b
Time of introduction (TI)						
ST	28.87	19.41a	53.33a	25.32a	95.64a	30.82a
2 WAP	28.92	19.07a	58.98a	24.28a	98.12a	30.76a
4 WAP	26.86	18.21a	54.32a	23.12a	96.48a	29.09a
PR x TI	*	Ns	*	*	Ns	

Values with the same letter(s) in the same column are not significantly different p≤0.5 at 5% level of probability by Duncan Multiple Range Test. S= Sorghum, C = Cowpea, WAP=Weeks after planting

Table 2: The effect of population density and time of introduction on Leaf area of sorghum at 8 WAP, 100 grain weight and grain yield

Population ratios	Leaf area at 8 WAP (cm^2)	100 grain weight (g)	Grain yield (kg/ha)
S : C			
100 : 100	266.39d	3.14a	1,160.68c
100 : 75	351.85c	3.35a	1,248.00bc
100 : 50	364.20c	3.08a	1,233.69bc
100 : 25	441.70a	3.87a	1,312.68b
100 -	394.75b	2.87a	1,634.75a
Time of introduction (TI)			
Same time	280.53c	3.08	1,177.71b
2 WAP	368.11b	3.22	1,319.53ab
4 WAP	442.77a	3.48	1,456.64a
PR X TI	*	Ns	*

Values with the same letter(s) in the same column are not significantly different p≤0.5 at 5% level of probability by Duncan Multiple Range Test. S= Sorghum, C = Cowpea, Lsd= Least significant different, WAP=Weeks after planting.

Table 3: The effect of population density and time of introduction on yield and yield components of cowpea

Population ratios (PR)	Number of branches plant	Number of pods/plant	Pod length (cm)	Number of seeds/pod	Weight of 100 seeds Cgm)	Grain yield (Kg/ha)
C : S						
100 : 100	1.64c	11.42b	15.47a	11.93	14.31	889.29c
100 : 75	1.69c	12.10b	14.88a	11.53	14.45	1064.75b
100 : 50	1.87bc	15.07b	15.03a	10.75	14.01	846.26c
100 : 25	2.89ab	15.52b	16.04a	11.97	14.37	583.38d
100 : --	3.98a	32.43a	16.23a	12.60	15.30	2708.73a
Time of introduction (TI)						
Same time	3.79a	25.40a	16.03a	12.36	14.86	1690.98a
2WAP	1.81ab	11.97b	15.25a	11.27	14.39	1208.56b
4WAP	1.25b	11.88b	15.15a	11.42	14.22	755.91c
PR X TI	*	*	NS	NS	NS	*

Values with the same letter(s) in the same column are not significantly different p≤0.5 at 5% level of probability by Duncan Multiple Range Test. S= Sorghum, C = Cowpea, Lsd= Least significant different, WAP=Weeks after planting.

Table 4: Interactive effect of population density and time of introduction on yield of cowpea and sorghum

Population ratios	Grain yield (Kg/ha) Same Time		Grain yield (Kg/ha) 2WAP		Grain yield (kg/ha) 4WAP	
S : C	S	C	S	C	S	C
100 : 100	1000.79	1470.56	1200.27	1024.83	1280.97	172.50
100 : 75	1030.93	1634.15	1351.57	1079.58	1361.50	480.83
100 : 50	1055.37	1559.05	1232.00	752.22	1413.70	227.50
100 : 25	1167.70	1082.43	1179.08	477.75	1592.27	189.97
Sole	1634.75	2708.73	1634.75	2708.73	1634.75	2708.73
Lsd						

Values with the same letter(s) in the same column are not significantly different p≤0.5 at 5% level of probability by Duncan Multiple Range Test. S= Sorghum, C = Cowpea, Lsd= Least significant different, WAP=Weeks after planting.

Table 5: Yield, land equivalent ratio (LER), Land equivalent coefficient (LEC), Aggressivity (A), and Monetary advantage index (MAI) in sorghum-cowpea intercropping in 2018

Population ratios										
				SAME TIME						
S	: C	LER	LEC	A		CR		MAI	Partial LER	
				S	C	S	C		S	C
100 :	100	1.15	0.33	0.07	-0.07	1.12	0.89	39,214.85	0.61	0.54
100 :	75	1.23	0.38	0.03	-0.03	1.40	0.71	61,257.96	0.63	0.60
100 :	50	1.22	0.37	0.06	-0.06	2.27	0.44	57,396.03	0.66	0.58
100 :	25	1.11	0.28	0.31	-0.31	7.1	0.14	23,252.77	0.71	0.40
Sole		1.00	0.25							
				2 WEEKS AFTER PLANTING						
		LER	LEC	A		CR		MAI		
				S	C					
100 :	100	1.11	0.27	0.35	-0.35	1.92	0.52	24,749.61	0.73	0.38
100 :	75	1.23	0.32	0.43	-0.43	2.07	0.36	50,499.51	0.83	0.40
100 :	50	1.03	0.21	0.47	-0.47	5.36	0.19	6,157.08	0.75	0.28
100 :	25	0.90	0.13	0.54	-0.54	4.00	0.06	-18,443.21	0.72	0.18
Sole		1.00	0.25							
				4WEEKS AFTER PLANTING						
		LER	LEC	A		CR		MAI		
				S	C	S	C		S	C
100 :	100	0.84	0.05	0.72	-0.72	13.00	0.08	-24,448.11	0.78	0.06
100 :	75	1.01	0.15	O.65	-0.65	4.88	0.15	1,791.29	0.83	0.17
100 :	50	0.94	0.07	0.78	-0.78	10.75	0.05	-9,397.08	0.86	0.08
100 :	25	1.04	0.07	0.90	-0.90	13.86	0.02	1,095.98	0.97	0.07
Sole		1.00	0.25							

Discussion

The observed significant reduction of grain yield of both cowpea and sorghum at the intercrop compared to their respective sole stand regardless of population density and time of introduction was possibly due to absence of competition for natural resources from the companion crop. Generally, the reduction in the yield of sorghum depended on component population of cowpea employed and the time of introduction. The yield increased as the population of component decreased and with further delayed in the time of introduction of cowpea. This observation is consistent with the findings of Oseni and Aliyu (2010), Karanja *et al.* (2014). In a similar study, Kunde *et al.* (2015), reported that intercropping cowpea with sorghum depressed sorghum yield and suggested simultaneous planting of the two crops for optimum productivity.

Yield and yield components of cowpea were significantly depressed by the time of introduction. Cowpea introduced to sorghum at 4 WAP significantly had poor grain yield compared to other planting periods. This reduction could be attributed to shading effect from associated sorghum. This observation agreed with the finding of Gandabbe *et al.* (2010) who reported a significant reduction in the yield of cowpea from associated maize due to delay in the time of introduction. The recorded poor yield of both crops at the combination ratio (100S:100C) could be attributed to crowding with attendant interspecific competition for natural resources by the two crops. The extent of yield reduction as observed in this study, was higher for cowpea when it was introduced to sorghum at 4WAP and also for sorghum when the crops were planted at the same time. Consider the following: That observation was expected because when the two crops were simultaneously sown, it was advantageous for cowpea since it grows faster than sorghum and had shaded the sorghum and hence, was able to utilize the natural resources better than sorghum. This is apparent in the significant reduction the number of branches and pods per plant of cowpea with further delayed to 4 WAP. This observation is similar to the finding of Karaja et al. (2014), who obtained the lowest grain yield sorghum and cowpea at the highest intercrop population.

From the present study, simultaneous planting of both crops as earlier reported (Gandebe *et al.*, 2010; Lamessa et al., 2015) to increase productivity will to a large extend depended on

population ratios employed, the time of introduction of companion crop, and which of the crops is to be considered as main crop for efficient utilization of natural resources in space and time dimensions. The intercropping advantage as measured by LER and LEC particularly at simultaneous planting as observed in this study is supported with the findings of several researchers (Oseni and Aliyu, 2010) in sorghum/cowpea system and Goosh (2004) in sorghum-groundnut intercropping due to complementarities of the two crops at this period of introduction of cowpea to sorghum. Introducing cowpea to sorghum at 4 WAP, the partial LER and LEC were higher for sorghum but with lower values for cowpea which make the combined LER and LEC respectively, lower than unity and 0.25 indicating that intercropping at this time of introduction was disadvantageous. This intercropping disadvantage could be attributed to high intra and interspecific competitions that exist between the two crops. The competition was high for sorghum particularly at reduced population of cowpea. This is corroborated with the high A and CR values for sorghum indicating its dominance in the mixture. This result is expected in view of the fact that sorghum being naturally taller than cowpea has been fully established and had shaded the cowpea that was sown at latter days.

Aggressivity which determines the competitive ability of component crops in an intercropping was positive for sorghum and negative for cowpea at all population ratios and time of introduction showing the dominance of sorghum over cowpea. This observation is in agreement with the findings of Oseni and Aliyu (2010) but contradicts Oroka and Omoregie (2007) who obtained a higher aggressivity in cowpea over rice at higher population densities. The discrepancy could be due to the fact that full population of sorghum was maintained whereas; the population of cowpea was reduced at different time of introduction. The higher CR values for sorghum over cowpea as well as positives A values had demonstrated that sorghum was more competitive than cowpea and the extent of competition increased with population ratios and the time of introduction employed. Delayed in the time of introduction of cowpea and reduction in the population density was found to increase A and CR values for sorghum over cowpea which eventually resulted into intercropping disadvantage at 4 WAP as observed in this study.

The positive MAI at simultaneous planting and at 2 WAP had shown that complementarity between the two crops in the utilization of natural resources was translated into economic benefit over their respective sole crops. A profitable economic return in 2S:1C and 1S:1C in sorghum- cowpea intercrop pattern had been earlier reported (Oseni and Aliyu, 2010). Dhina *et al.* (2007), opined that if LER values were high as observed in this study, then there could be economic benefit expressed with MAI.

Conclusion

The present study has revealed that the complementarity in sorghum/cowpea intercrop will, to a large extend, depend on the population ratio employed and time of introduction of component crop. Although, simultaneous planting the two crops demonstrated intercropping advantage over other periods of introduction for efficient utilization of natural resources that was translated into economic profitability, population ratio 100C:75C with the highest value is recommended for adoption in sorghum/cowpea mixture.

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