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Full Length Research Paper

Effect of mounding times on yield of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces in Sahel-Burkina Faso

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Bambara groundnut (*Vigna subterranea* (L.) Verdcourt) was grown in the Sahel area of Burkina Faso in 2010 and 2011. Three mounding periods – 2 WAS (two weeks after sowing), 4 WAS and 7 WAS – were combined with two landraces in a randomized complete block design experiments (RCBD). These two landraces showed significant differences (P<0.05) for seed yield per plant, one hundred seeds weight and average yield. Mounding at 4 WAS induced a delay of 50% flowering (14 to 15 days) in comparison to mounding at 2 and 7 WAS. Mounding at 4 WAS reduced seed yield per plant by 9% in comparison with mounding at 2 WAS and by 29% in comparison with late mounding at 7 WAS. Mounding at 2 and 7 WAS led to the highest seed yield across the two years. Late timing at 7 WAS generated an average annual yield of 1461 kg/ha, followed by early mounding at 2 WAS with1144 kg/ha and medium mounding at 4 WAS with 887 kg/ha. Therefore, in the Sahelian agro ecological zone, farmers must avoid mounding at 4 WAS for landraces having a cycle which takes less than 90 days because it has a significant negative impact on Bambara groundnut yield.

Key words: Bambara groundnut, mounding, yield, Sahel, agro ecology, landrace.

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdcourt) is part of people diet in all Sub-Saharan Africa (Goli, 1997). The world annual production of voandzou was estimated at about 330,000 t per year (PROTA, 2006). Burkina Faso, Chad, Côte d'Ivoire, Ghana, Mali, Niger and Nigeria in West Africa provide 45 to 50% of world production. In Burkina Faso, Bambara groundnut is produced in pure stand and the annual production is about 45 000 ton. This African native legume is mainly grown by women in the three major agro ecological zones. From South to North, we have the Sudan agro ecological zone (900 to 1200 mm of annual rainfall), the Sudano-Sahelian agro ecological zone (600 to 900 mm of (300 to 600 mm of annual rainfall). Bambara nut is mostly produced in pure stand even if some farmers mix it with peanut. It is recognized to be highly tolerant to drought (Mwale et al*.,* 2007; Jørgensen et al., 2010, 2011). In Burkina Faso, the cropping system of Bambara groundnut is characterized by sowing one seed per hole in a ploughed soil, followed by manual mounding. Such agricultural practice consists in bringing soil to the crown of the plant with a hand hoe.

There are various mounding periods and farmers argue that this agricultural practice improves Bambara groundnut production (Brink et al., 1995; Ntundu, 2002; Sesay et al., 1995). Many authors have shown the benefit of mounding as source of organic fertilization through weeds' decomposition (Adenawoola et al., 2005; Adjei-Nsiah et al., 2004) and a method of soil aeration and drainage (Salako et al., 2006). Results of the direct influence of mounding on flowering examined by Balole et al. (2003) showed that the influence of this agricultural

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practice on flowering can reduce yield. However, there is few available data and results on the influence of mounding periods on Bambara groundnut yield. The objective of this investigation is to assess the influence of mounding periods on Bambara groundnut yield in the Sahelian agro ecological zone of Burkina Faso.

MATERIALS AND METHODS

Study site

Experiments carried out on the site of Pobé (13° 54' 01.6" North, 001° 44' 54.0" West). The site is located in the Northern Sahelian phytogeographical zone (Fontes and Guinko, 1995). The Sahelian climate is characterized by two seasons, a rainy season which lasts three months (July to September), and a dry season which takes nine months (October to June). Annual rainfall ranges from 300 to 600 mm. A soil analysis carried out in 2011 showed that soils of Pobé contain very little nitrogen and phosphorus. The following results were obtained: total N (0.063%), phosphorus (<0.4 mg/100 g), calcium (16 nmol/kg), potassium (1.2 nmol/kg), magnesium (2.7 nmol/kg), sodium (< 1.0 nmol/kg), humus (< 1.6%), organic carbon (from total organic content: 0.844%), clay (6%), silt (14%), sand (80%) and pH (6.2). The soils of Pobé have a very low fertility rate; it is therefore a challenge for farmers to get a good production every year in such farming environment.

Experimental design

Experiments were made during the rainy seasons of 2010 and 2011 (Table 1). The experimental layout was randomized complete block design with four replications. Factors were landrace and mounding time. Two landraces KVS235 (Kamboinse Vigna Subterranea) and KVS246 and three mounding times were factors' levels. KVS235 has a white seed coat without eye while KVS246 has a brown seed coat with a butterfly like eye. The three mounding periods were: (i) mounding at 2 WAS (two weeks after sowing), (ii) at 4 WAS and (iii) at 7 WAS. Mounding consisted in bringing soil to the crown of plant with a hoe.

Early mounding was carried out at 2 WAS, followed by middle mounding at 4 WAS carried out four to five days before the first flowers appear and late mounding at 7 WAS corresponding to the end of flowering and the beginning of pod development and seed filling. Each plot comprised 11 rows of 2 m × 2 m; that is, a plot size of 4 m^2. The distance between rows was 0.4 m, and distance between seeds was 0.2 m. The distance between plots was 0.5m and that between replications was 1 m. A total of 66 seeds were sown in each ploughed plot. Data were collected on central rows of each plot.

Data collection and analysis

Several characteristics were recorded according to Bambara groundnut descriptors (IPGRI IITA, BAMNET, 2000): time of first flower opening (FLO), date of 50% flowering plant per plot (FLO50), shelling percentage (SHELLP), seed weight per plant (SWGTP), seed length (SEEDL), seed width (SEEDW), one hundred seeds weight (100SWGT) and average yield (YLD). Time of first flower opening (number of days) in the plot is the number of days from sowing to the first fully open flower in one plant. The date of 50% flowering is the number of days from the date of sowing to the date on which 50% of plants in the plot flowered. After harvest, the number of plants per plot was recorded and pods were dried under sun. All pods were weighted and after that, all seeds were removed from the pods and weighted again. The seed weight per plant (g) is obtained by dividing the total weight of seed (g) by the number of plants harvested. The shelling percentage (%) is the quotient in percent of the total weight of seeds compared to the total unshelled pods. Seed length (mm) was the average of length (mm) of 10 seeds randomly chosen from each elementary plot. Likewise, seed width (mm) also was the average of width (mm) of 10 seeds randomly chosen. The hundred seeds weight (100SWGT) is the weight (g) of 100 randomly chosen seeds and average yield ($g*m^{-2}$) was determined as the ratio of total seed weight (g) on the area of plot (m^2). Statistical analysis was carried out using the statistical package GenStat Tenth Edition (VSN International, 2011). The significance level was setup at $\alpha = 0.05$. The separation of means was done by the method of least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

These two varieties showed differences in their characteristics (Table 2) during these two years. In 2010, varieties emerged at 63 ± 6% (KVS235) and at 62 ± 9% (KVS246) while in 2011, emergence rates were respectively 85 ± 11 (KVS235) and 84 ± 6 (KVS246). Annual rainfalls of the site were 439 in 2010 and 412 in 2011. 6% decrease of rainfall was observed (Table 1). Plants have been exposed to water stress in August 2011 and also to a terminal drought in October 2011 (Table 1). Annual average temperatures in 2010 and 2011 were respectively 30.7 ± 3.64°C and 30.3 ± 3.93°C. But during critical stage of pod filling in October, it was recorded 31.3°C in 2010 and 32.4°C in 2011. Average emergence rates of the two varieties were similar. As shown in Table 2, the two landraces are similar in date of appearance of first flower, date of 50% flowering, shelling percentage, seed length and width. Significant differences exist between them for yield per plant (P=0.0025), one hundred seeds weight (P=0.0450) and average yield (P=0.0177). So, they are both suitable for growing in the Sahelian agro-ecological area.

Time to flowering

The time of appearance of the first flower (FLO) of the two landraces is similar (Table 2) and the data of the two years did not show significant statistical difference at alpha level 0.05 (*P*=0.2929). Mounding time did not influence the apparition of the first flower of the two landraces. At Pobé, in 2010, early mounding (2 WAS) and late mounding (7 WAS) are similar and they delayed the appearance of the first flower by 1 to 2 days in comparison with mounding at 4 WAS (Table 3). In 2011, a two-day delay was observed on these three mounding time treatments and no significant difference was observed. A contrasting delaying influence of mounding at 4 WAS was observed in comparison to 2011 results. Finally, the results of the two years showed that there is no significant influence of the mounding period on the

Table 1. Rainfall of Pobe in 2010 and 2011 (mm).

Year	May	June	July	August	September	October	Total
2010	0	37.0	97.5	158.0	85.0	61.5	439.0
2011	0	122.0	80.5	127.5	73.5	8.0	411.5
Difference	0	85.0	-17.0	-30.5	-11.5	-53.5	-27.5

date of the first flower appearance, even if light delay was observed on mounding at 4 WAS (Table 3). At Pobé, the first flower of the two landraces appeared 31 ± 2 days. Mounding at 4 WAS coincides with the beginning offlowering of these landraces that have a 90-day cycle. The observed number of days to 50% flowering of the two landraces is also analogous (Table 2). Significant higher difference (P < 0.001) was observed for 50% flowering time (Table 3) due to the timing of mounding. Across years, late mounding (7 WAS) led to the earliest flowering, followed by early mounding (2 WAS) and plots with mounding 4 WAS had the latest flowering (Table 3). In 2010, a 13 to 15 day delay was observed while in 2011 the delay was 14 to 15 days. The data of the two years show that there was a 14 to 15 day delay for 50% flowering with mounding treatment at 4 WAS. Experiment was carried out in a sandy soil in Pobé and the light structure of soil explains the fact that the three mounding times do not differ in time of first flower appearance. The time to first flowering and 50% flowering are positively correlated; it is therefore consistent that mounding at 4 WAS induced a delay of the first flowering and 50% flowering in comparison to mounding at 2 and 7 WAS. That delay in the appearance of the first flower and in 50% flowering for mounding at 4 WAS can be explained by the fact that the nodes of plants are covered due to mounding. So, plants mobilized extra energy and time to get flower out of soil in comparison to plant under mounding at 2 and 7 WAS.

Shelling

The two tested landraces have a similar shelling percentage (Table 2). In 2010 and 2011, shelling percentage was similar for early mounding, middle mounding and late mounding periods (Table 3). Shelling percentage is higher than 70% for the three mounding periods in Pobé. This means that all mounding times generated a good filling of pods. Agro ecological conditions (soil structure, temperature and rainfall) that allow the expression of the genetic potential of the two landraces and the sandy soil structure explain the high rate of pod filling under the three mounding periods.

Seed weight per plant

There were significant differences between the two landraces (Table 2). KVS246 had consistently higher seed weight per plant. It has 26% more seed weight per plant than KVS235 across the two year period. The timing of mounding significantly affected the seed weight per plant in 2010 (P = 0.0142) and in 2011 (P < 0.001). In 2010 as well as in 2011, a clear impact of the timing of mounding on seed weight per plant was observed (Table 3). In 2010, mounding at 2 WAS induced an increase in seed weight by 10% in comparison with mounding at 4 WAS, whereas mounding at 7 WAS induced an increase on seed weight per plant of 35% in comparison with mounding 4 WAS. In 2011, mounding at 2 WAS led to an increase of 17% in comparison with mounding at 4 WAS, while mounding at 7 WAS induced an increase of 130% in comparison with mounding at 4 WAS (Table 3). On average across the years, the smallest seed yield was produced by mounding at 4 WAS. This period reduces the productivity of seed per plant probably due to the disturbance in flowering process and extra mobilization of energy to produce flowers above the mounds. Mounding at 4 WAS reduced seed yield per plant by 9% in comparison with mounding at 2 WAS. This middle mounding at 4 WAS reduced again seed yield per plant by 29% in comparison with late mounding at 7 WAS. Mounding at 2 and 7 WAS led to the highest seed yield across the two years. The physical structure of five different soils are reported to affect the penetration of pegs through the soil surface, that may have capped, and thus soils disturbance (mounding) can improve pod development and seed filling of bambara groundnut (Uguru and Ezeh, 1997). The soil of Pobé is sandy and this explains why it is not very difficult for flowers to be brought out of the crown at any mounding period. The significant impact of mounding at 7 WAS on seed yield per plant in Sahel-Burkina is probably due to the fact that late mounding acted as a watershed and allowed a better continuous downward migration of carbohydrates to pods and seeds.

Seed length and width

On the Pobé site there was no difference between the two landraces in terms of seed length (Table 2). There were significant differences for seed length in 2010 (P = 0.0302) but not in 2011 (P = 0.1430) according to mounding periods (Table 3). During 2010, the impact of mounding periods was clear and different for the three mounding periods (least significant difference = 0.62):

Table 2. Physiologic and agronomic characteristics of 2 Bambara groundnut landraces in 2010 and 2011 at Pobé in Sahel agroecological zone (data averaged across 3 mounding treatments (average ± standard deviation).

Year	Landrace	n	FLO	FLO50	SHELLP	SWGTP	SEEDL	SEEDW	100SWGT	YLD
			# days	# days	%	g plant^{-1}	mm	mm	g	g/m^2
2010	KVS235	12	31.08 ± 1.00	39.08 ± 6.83	72.50 ± 4.24	17.36 ± 2.92^b	11.71 ± 0.55	9.85 ± 0.52	62.50 ± 11.23	192.02 ± 43.09^b
	KVS246	12	30.75 ± 0.87	39.08 ± 7.18	71.58 ± 4.12	22.38 ± 5.50^a	11.68 ± 0.71	9.91 ± 0.63	66.22 ± 8.73	225.14 ± 54.88^a
	P-value		0.2396	-	-	0.0042	-	-	0.2709	0.0160
2011	KVS235	12	31.25 ± 5.03	41.17 ± 7.09	69.50 ± 21.46	1.76 ± 1.70	9.50 ± 0.62	8.30 ± 0.46	38.16 ± 11.49	24.69 ± 23.49
	KVS246	12	29.92 ± 0.29	41.67 ± 7.69	74.33 ± 7.03	1.73 ± 1.51	9.84 ± 0.50	8.28 ± 0.47	43.00 ± 6.18	23.82 ± 21.34
	P-value		-	-	-	-	0.1027	-	0.0702	-
Average 2010/2011	KVS235	24	31.17 ± 3.55	40.13 ± 6.89	70.96 ± 15.20	9.56 ± 8.31^b	10.61 ± 1.26	9.08 ± 0.93	50.33 ± 16.68	108.35 ± 91.96^b
	KVS246	24	30.33 ± 0.76	40.38 ± 7.39	72.96 ± 5.81	12.06 ± 11.26^a	10.76 ± 1.11	9.09 ± 1.00	54.61 ± 13.98	124.48 ± 110.59^a
	P-value		0.2929	-	-	0.0025	-	-	0.0450	0.0177

n= sample size; FLO: time to first open flower; FLO50: date of 50% flowering plant per plot; SHELLP: shelling percentage; SWGTP: seed weight per plant; SEEDL: seed length; SEEDW: seed width; 100SWGT: 100 seeds weight; YLD: average yield.

Late mounding at 7 WAS ranked first (12.08 ± 0.29 mm), followed by middle mounding at 4 WAS (11.79 ± 0.72 mm) and early mounding at 2 WAS (11.22 ± 0.49 mm).

There were no differences between the two landraces in terms of seed width (Table 2). No significant differences were found in seed width in 2010 (P = 0.1148) and 2011 (P = 0.0787) according to mounding periods (Table 3). After flowering, Bambara groundnut elongates the pegs with the fertilized flowers, which are driven by positive geotropism in the soil, where pod development and seed filling occurs (Doku and Karikari, 1970). Bambara groundnut in response to growing conditions in terms of mounding time, soil structure and water availability can increase seed length more than seed width. This potential on seed length increase is probably under genetic control and may be influenced by reduced drought stress as in 2011.

100 seed weight

Over the two years, results showed that the two landraces have different 100 seed weight (Table 2). The one hundred seeds weight obtained in 2010 under middle mounding at 4 WAS (65.21 g) and late mounding at 7 WAS (71.71 g) were similar (Table 3). They are different (P = 0.0050) from 100 seeds weight under early mounding 2 WAS (56.15 g). But, in 2011, no difference was made in the three treatments (P = 0.1439). Combined data from 2010 and 2011 showed that the 100 seed weight of middle mounding at 4 WAS (54.64 g) and late mounding at 7 WAS (55.79 g) were similar (Table 3).

They are different (P = 0.0050) from 100 seeds weight under early mounding at 2 WAS (46.97 g). Here also, the soil structure is the key explanation of the performance of middle mounding and late mounding in comparison to early mounding. 100 seeds weight was also negatively influenced by intra cycle drought observed in 2011.

Average yield

The average yield per unit area of the two landraces was different in 2010 (P = 0.0160) with yields were very low and similar in 2011 due

Table 3. Effects of mounding times on Bambara groundnut agronomic and physiologic characters in 2010 and 2011 at Pobé in Sahel agroecological zone (average ± standard deviation under parenthesis).

Year	Mounding weeks after sowing	n	FLO # days	FLO50 # days	SHELLP %	SWGTP g plant^{-1}	SEEDL mm	SEEDW mm	100SWGT g	YLD g/m^2
2010	2	8	31.50 ± 0.93[a]	35.13 ± 0.35[b]	72.25 ± 4.89	19.02 ± 5.21[b]	11.22 ± 0.49[b]	9.53 ± 0.52	56.15 ± 8.19[b]	208.88 ± 43.86[b]
	4	8	30.00 ± 0.00[b]	48.5 ± 0.53[a]	71.38 ± 3.76	17.30 ± 4.37[b]	11.79 ± 0.72[ab]	9.97 ± 0.70	65.21 ± 8.63[a]	162.07 ± 28.52[c]
	7	8	31.25 ± 0.71[a]	33.63 ± 0.74[c]	72.50 ± 4.08	23.30 ± 3.80[a]	12.08 ± 0.29[a]	10.15 ± 0.23	71.71 ± 6.98[a]	254.79 ± 30.68[a]
	P-value		0.0009	0.0000	-	0.0142	0.0302	0.1148	0.0050	0.0001
2011	2	8	30.13 ± 0.83	36.88 ± 1.36[b]	68.38 ± 21.14	1.37 ± 1.13[b]	9.50 ± 0.71	8.28 ± 0.52	37.79 ± 12.29	20.00 ± 16.07[b]
	4	8	31.75 ± 6.18	51.25 ± 1.04[a]	70.88 ± 16.14	1.17 ± 1.03[b]	9.96 ± 0.52	8.49 ± 0.45	44.07 ± 8.40	15.36 ± 12.83[b]
	7	8	29.88 ± 0.35	36.13 ± 1.83[b]	76.50 ± 8.51	2.69 ± 2.05[a]	9.55 ± 0.41	8.10 ± 0.35	39.88 ± 6.51	37.40 ± 29.20[a]
	P-value		-	0.0000	-	0.0007	0.1430	0.0787	0.1439	0.0011
Average 2010/2011	2	16	30.81 ± 1.11	36.00 ± 1.32[b]	70.31 ± 14.96	10.19 ± 9.81[b]	10.36 ± 1.07[b]	8.90 ± 0.82	46.97 ± 13.85[b]	114.44 ± 102.62[b]
	4	16	30.88 ± 4.32	49.88 ± 1.63[a]	71.13 ± 11.32	9.23 ± 8.88[b]	10.87 ± 1.12[a]	9.23 ± 0.95	54.64 ± 13.67[a]	88.72 ± 78.71[c]
	7	16	30.56 ± 0.89	34.88 ± 1.86[c]	74.50 ± 6.78	12.99 ± 11.04[a]	10.82 ± 1.35[a]	9.12 ± 1.09	55.79 ± 17.69[a]	146.09 ± 115.93[a]
	P-value		-	0.0000	0.6827	0.0009	0.0203	0.1422	0.0026	0.0000

n= sample size; FLO: time to first open flower; FLO50: date of 50% flowering plant per plot; SHELLP: shelling percentage; SWGTP: seed weight per plant; SEEDL: seed length; SEEDW: seed width; 100WGT: 100 seeds weight; YLD: average yield.

essentially to intra cycle drought (about 240 kg/ha). Significant differences were observed in effects of mounding periods on average yield (Table 3) in 2010 (P < 0.001) and 2011 (P = 0.001). In 2010, a higher average yield was obtained with mounding at 7 WAS (254.80 g m^{-2}) compared to yields at 2 WAS (208.90 g m^{-2}) and 4 WAS (162.1 g m^{-2}). In 2010, mounding at 2 WAS led to 298% increase compared to mounding at 4 WAS. Plots mounded 7 WAS showed an average increase of 57% in comparison with mounding at 4 WAS. In 2011, a high yield was recorded on average in plots with mounding at 7 WAS (37.40 g m^{-2}) compared to the yield in plots with mounding at 2 WAS (20.00 g*m^{-2}) and 4 WAS (15.36), which were similar. Inter-annual variability of rainfall influenced Bambara groundnut average yield. Intra cycle drought in August 2011 and the lack of rain in October 2011 (terminal drought) during the stage of pod filling had a negative impact on yields, which were very low. Over the two years, mounding at 2 and 7 WAS had the highest average yield while mounding at 4 WAS had the lowest. By mounding 2 WAS, instead of 4 WAS average yield increased by 29%, while mounding at 7 WAS instead of 4 WAS led to an increase of 65% on average yield throughout the two years. In the Sahelian agro-ecological area, mounding yields more at 7 WAS throughout the years. The average yield was positively influenced by mounding at 7 WAS as this time corresponds to the crucial stage of pod filling. Late mounding has favored storage of carbohydrates in seeds by reducing impact of terminal drought stress. Water stress in October during pod filling coupled with high temperature explains the decrease of average yield in 2011. Water availability, temperature and mounding time explain the variability of average yield throughout years in

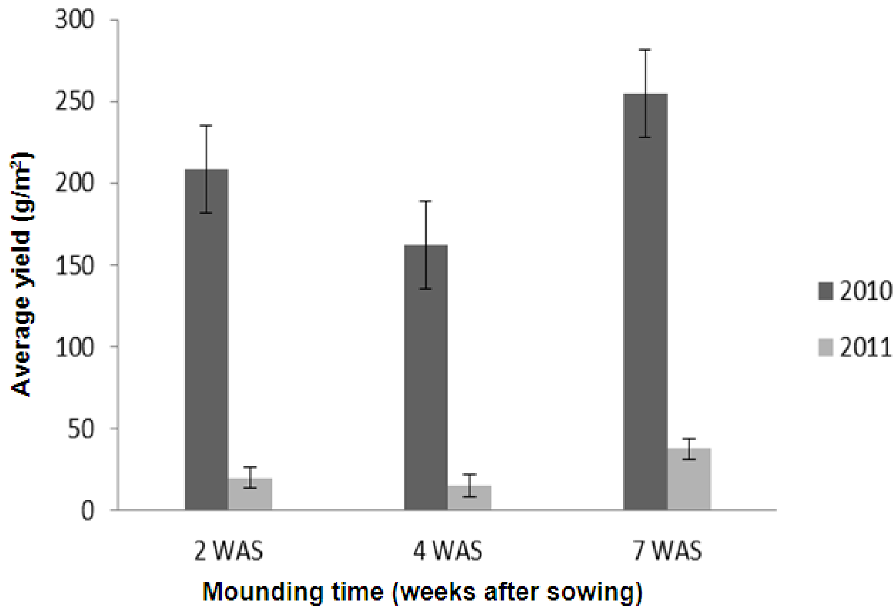

Figure 1. Average yield variability according to mounding time and year (bars of standard errors).

the same location (Figure 1). These results are in accordance with Vurayai et al. (2011). These authors studied effects of water stress on Bambara groundnut in greenhouses and showed that drought stress occurred on Bambara groundnut during vegetative phase reduced 100 seeds weight by 34% and the yield by 47% in comparison to the non-stressed plants. When drought occurred during flowering time, the 100 seeds weight was reduced by 20% and yield by 72%. Lastly, when drought stress took place during pod filling stage, the 100 seeds weight was reduced by 64% and yield by 78%.

Conclusion

Mounding periods influence Bambara groundnut physiological and agronomic characters in Sahel-Burkina Faso. Mounding should be made early (about 2 WAS) or late (7 WAS) but not at 4 WAS on Bambara groundnut landraces maturing before 90 days. Mounding at 4 WAS reduced significantly average yield. Late mounding at 7 WAS should be promoted because it yields 22% higher than the early mounding at 2 WAS and 64% than middle mounding at 4 WAS.

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