Morpho-phenological variation in *Lablab purpureus*

S.U. EWANSIHA[1], U.F. CHIEZEY[2], S.A. TARAWALI[1, 3] AND E.N.O. IWUAFOR[2]
[1] *International Institute of Tropical Agriculture (IITA), Kano Station, PMB 3112, Kano, Nigeria*
[2] *Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria*
[3] *International Livestock Research Institute, Addis Ababa, Ethiopia*

Abstract

The morphological and phenological variations in 46 accessions of *Lablab purpureus* were evaluated in 2000 and 2001 at Samaru, Zaria in the moist savanna zone of Nigeria. Accessions were classified into various groups according to plant structure, flowering time, and pod and seed characters. Based on flowering time, 6 maturity groups were identified: very early (40–50 days after planting) (7 accessions), early (51–60 days)(20), intermediate (61–80 days)(4), late (91–110 days)(6), very late (111–130 days)(8) and extremely late (131–150 days)(1). In 140 days, nitrogen production increased from 15 kg/ha for the very early-flowering accessions to 159 kg/ha for the late-flowering accessions and then decreased to 135 kg/ha for the extremely late-flowering accession with a mean nitrogen yield of 64.1 kg/ha. Fifteen accessions were identified as having potential for fresh pod production and 11 accessions for grain with a smaller number suitable for both grain and fodder production.

Introduction

Lablab purpureus (lablab) is a multi-purpose crop used for soil improvement, soil protection and weed control. It is especially important for food and fodder (Schaaffhausen 1963; Kay 1979; NAS 1979; Wood 1983), and can be grown as a component crop in mixed farming systems (NAS 1979). In northern Nigeria, lablab provides food for humans, fodder for livestock and income (Bhat and Etejere 1985; Thomas and Sumberg 1995; Iwuafor and Odunze 2000; Adeoye and Onifade 2000). Increasing use of lablab within the mixed crop-livestock farming systems would increase the availability of livestock feed, while improving soil fertility and providing food for the people at the same time from the same piece of land.

However, lablab is highly phenotypically variable (Shivashankar and Kulkarni 1989a), adapting to diverse environments (NAS 1979; Kay 1979; Duke *et al.* 1981). According to Pengelly and Maass (2001), phenology is an important factor in determining accessions that can provide better forages and improved crop residue utilisation in mixed production systems. Phenology also has an overriding influence in determining general adaptation to different ecological areas and to duration of growing season, plus resource capture and use in plants (Shorter *et al.* 1991; Richards 1993) and in lablab, an accession which flowers in one region may not flower in another (Schaaffhausen 1963; Das 1990). A range of accessions of lablab were received from Texas A and M University, United States of America, International Livestock Research Institute (ILRI), Ethiopia, International Institute of Tropical Agriculture (IITA), Nigeria and National Animal Production Research Institute (NAPRI), Nigeria in 1998–99. A program to evaluate their performance in the moist savanna region of west Africa was commenced. This paper reports the morpho-phenological evaluation of these various accessions of lablab.

Materials and methods

Materials

The experiment was conducted during the growing seasons in 2000 and 2001 at the research farm of the Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Samaru,

Correspondence: S.U. Ewansiha, IITA, PMB 3112, Kano, Nigeria. E-mail: suewansiha@yahoo.com

Zaria in the moist savanna zone of Nigeria (11°11′N, 07°38′E; elevation 686 m). The zone has a leached ferruginous tropical soil with 30–40% clay, a rainy season from May-October with an average annual rainfall of 1000 mm and a growing period of 151–180 days, together with a daily mean temperature of 20°C during the growing season (Kowal and Kassam 1978; Jagtap 1995). Rainfall and temperature during the trial, measured at the IAR weather station adjacent to the trial field, are given in Table 1. Soil at the experimental site prior to planting had a pH of 5.0 (H_2O), a total nitrogen content of 0.06%, a C: ratio of 9.20 and available P (Bray-I) content of 7.5 mg/kg. Exchangeable acidity and effective cation exchange capacity were 0.80 and 3.90 cmol (+)/kg soil, respectively. Forty-six lablab accessions were studied.

Experimental establishment and management

The experiment was laid out as a randomised complete block design with 3 replications and a plot size of 6 × 3 m with 0.5 m between plots. Each plot had 4 rows 75 cm apart with plants 30 cm apart within rows. In both years, hand hoes were used to make ridges following an initial harrow in Year 1. On July 1, 2000 and 2001, 2 unscarified and uninoculated seeds were planted in each hole and later thinned to 1 plant per hill at 3 weeks after planting (WAP). At planting in both growing seasons, 30 kg/ha P was applied. Benomyl fungicide (50% w/w benomyl) at a rate of 10g/L of water was used to treat 1 kg lablab seed before planting. Plants were sprayed with benomyl fungicide at the rate of 130 g/20L of water, at 2-week intervals between 8 and 15 weeks after planting, to control fungal disease. During the vegetative, flowering and podding stages, plants were sprayed with Sherpa plus (Aventis Crop Science, France; 20 g/L cypermethrin, 250 g/L dimethoate) at the rate of 1.0 L/ha as soon as insects were noticed.

Morphology and phenology

Time to reach 50% flowering (when 50% of plants in a plot had flowers) was recorded, and accessions were classified into 6 flowering groups: (1) very early (40–50 days after planting); (2) early (51–60 days); (3) intermediate (61–80 days); (4) late (91–110 days); (5) very late (111–130 days); and (6) extremely late (131–150 days). Soil cover (the percentage of the plot covered by lablab) was estimated at 50% flowering by placing a 1 × 1 m quadrat along the middle 2 rows at 2 points per plot. Plant height (from the ground to the top of the canopy for 3 plants per plot) was measured at 50% flowering and used to classify accessions into 3 groups: (1) low-growing (<51 cm); (2) intermediate-growing (51–70 cm); and (3) tall-growing (>70 cm). Size of 3 leaves per plant, based on 3 plants per plot, was measured on the middle leaflet at 50% flowering. Leaf length was measured from base to tip of the leaflet and width at the widest point, and leaf size was classified into 3 groups: (1) small (leaf length, leaf

Table 1. Rainfall and temperature at experimental site during the trial period.

Month	2000			2001		
	Rainfall (mm)	Temperature (°C)		Rainfall (mm)	Temperature (°C)	
		Min	Max		Min	Max
Jan	0	18	33	0	15	31
Feb	0	16	36	0	17	32
Mar	0	21	37	0	22	37
Apr	0	24	38	84	24	36
May	35	25	37	160	24	35
Jun	210	22	28	178	23	32
Jul	238	22	29	313	22	30
Aug	245	23	29	361	22	30
Sep	182	21	30	256	22	31
Oct	78	20	33	0	20	33
Nov	0	15	32	0	16	33
Dec	0	17	31	0	16	33
Total	988			1352		

width <11 cm); (2) intermediate (11–12 cm); and (3) large (>12 cm). Leaf ratio (leaf length: leaf width) was calculated. The following measurements (length of peduncle, length of raceme and number of nodes having pods) were made on 3 inflorescences per plant, on 3 plants per plot, when all buds had opened and formed pods. The length of 10 mature, dry pods per plot was measured and used to classify accessions into 3 groups: (1) short (<6 cm long); (2) medium (6–7 cm); and (3) long (>7 cm). Leaf and stem colours were observed at 50% flowering and grouped into: (1) green; and (2) purple. Flower colour formed 2 groups: (1) white; and (2) purple. Pod colour also formed 2 groups: (1) green; and (2) purple. Seed colour was recorded before planting and after harvest and formed 5 groups: (1) black; (2) green; (3) purple; (4) brown; and (5) white/cream. For accessions with more than 1 seed colour, only the dominant seed colour was recorded. Pod shape was either (1) flat or (2) inflated.

Emergence, establishment and pod, seed, biomass, nodule and nitrogen production

Plots were observed daily and number of seedlings was recorded. Seedling emergence, defined as the number of days when 50% of the plants in a plot had emerged, was calculated. Field establishment was determined by counting seedlings at 6 weeks after planting. Pods in a unit area, still bearing their seeds, were harvested when they were mature and had become mechanically threshable, and were weighed to obtain pod yield (outer pod case+seed). Seeds were removed from the pods and weighed to provide seed yield. At 50% flowering, a 1.5×1 m quadrat, positioned at 0.5 m from the plot end, was placed on plants along the middle 2 rows. Plants within the quadrat were cut at 15 cm above ground level, separated into leaves and stems and weighed immediately. Sub-samples of 200 g fresh material of leaves and stems were weighed, oven dried at 65°C for 48 hours and re-weighed. Using a garden fork, roots of cut plants were carefully dug out, washed in a bowl of water, weighed and oven-dried. Before weighing the roots, the stem base attached to the roots was cut off using a knife. Nodules from the roots were counted and their effectiveness determined by recording nodules with pinkish colouration. Dry matter yields of leaves, stems and roots were calculated. Leaf and stem samples from the 2000 growing season were dried, ground and sieved using a 1 mm sieve and analysed for N concentration, according to the analytical procedure described by IITA (1982). N yield of biomass was determined by adding N contents of leaf and stem.

Statistical analysis

Analysis of variance was carried out using the PROC GLM procedure of SAS program (SAS Institute 1999). The correlation between the observed attributes was determined and principal component analysis (PCA) was performed with PRINCOM procedure also of SAS program.

Results

Morphology and phenology

The correlation matrix of the PCA identified strong, positive correlations between plant height and soil cover at 50% flowering ($r=0.84$; $P<0.0001$). The relationships between leaf, inflorescence and pod dimensions were positive and there was a very strong correlation between leaf length and leaf width at 50% flowering ($r=0.93$; $P<0.0001$). The most important attributes were determined: where 2 attributes where strongly correlated ($r>0.71$), one was omitted and PCA was re-run for the selected attributes. The first 3 principal components explained 83% of the total variation (Table 2). PRIN 1 was related to plant height and time to 50% flowering. Pod length influenced PRIN 2. PRIN 3 described leaf and pod length. Based on these findings, plant height, leaf size, pod size and time to 50% flowering were identified as the most important attributes and were used in morpho-phenological (quantitative) grouping (Table 3): 27 accessions had low plant height (<51 cm), 4 had intermediate plant height (51–70 cm) and 15 accessions were tall-growing (>70 cm); 7 accessions belonged to the very early flowering group, 20 to early, 4 to intermediate, 6 to late, 8 to very late and 1 to extremely late; 17 accessions had small leaves, 10 had intermediate leaf size and 19 had large leaves; 31 accessions had short pods, 11 had medium pods and 4 had long pods.

For the qualitative morphological attributes, the correlation matrix of the PCA identified significant positive correlations between leaf colour and pod colour ($r=1.00$; $P<0.0001$). Seed colour was negatively related to colour of other plant parts (leaf, stem, pod and flower), with a strong relationship with flower colour ($r=-0.87$; $P<0.0001$). On the basis of leaf, stem, flower and seed colours as well

Table 2. Eigenvalues of the correlation matrix and eigenvectors of the first 3 Principal Components.

EIGENVALUES	PRIN 1[1]	PRIN 2	PRIN 3
Eigenvalue	3.45	1.63	0.72
CPV[2]	49%	73%	83%
Variable		Eigenvectors	
Plant height at 50% flowering	0.45	–0.33	0.18
Leaf length at 50% flowering	0.42	–0.12	0.51
Peduncle length	0.29	0.46	–0.30
Raceme length	0.39	0.40	–0.21
No of flower nodes/raceme	0.40	0.25	–0.24
Pod length	–0.08	0.59	0.72
Time to 50% flowering	0.46	–0.31	0.07

[1] First principal component.
[2] CPV—% cumulative proportion of variation.

as pod shape, 11 groups of accessions were identified (Table 4). Forty accessions had green leaves, while 6 were purple; 33 accessions had green stems and 13 had purple stems; 25 accessions had white flowers, while 21 had purple flowers. Three accessions (BARSD 1, TLN 9 and Grif 1246) showed both flower colours in a plot, with plants displaying white flowers being more common. For accession Grif 1246, a single plant could show both flower colours; sometimes the flower opened as purple

Table 3. Morphological (quantitative) and phenological grouping of lablab accessions.

PH/LS[1]		Very early-flowering		Early-flowering		Intermediate-flowering		Late-flowering	Very late-flowering	Extremely late-flowering
		Pod size 2	Pod size 3	Pod size 1	Pod size 2	Pod size 2	Pod size 3	Pod size 1	Pod size 1	Pod size 1
I	a	PI 388019, PI 392369, Grif 12293, PI 416699	PI 555670	PI 284802, PI 596358, TLN 13, PI 388018, PI 288467 PI 288466, PI 388017, PI 542609, PI 183451, PI 388003	PI 322531					
I	b	PI 346440	PI 439586	TLN 6, PI 338341, TLN 9, PI 388012, PI 164772	Grif 969, PI 337534, PI 509114					
I	c			PI 388013						
II	a						PI 532170			
II	c					BARSD 1, PI 345608	Grif 1246			
III	c							ILRI 147, ILRI 7279, PI387994, PI 401553 TLN 7, TLN 29	PI 164302, ILRI 4612, ILRI 6930, ILRI 730, ILRI 7403, NAPRI 2, NAPRI 3, NAPRI 4	PI 195851

[1]PH – plant height: (I) low-growing (<50 cm), (II) intermediate-growing (51–70 cm), (III) tall-growing (>70 cm); LS – leaf size group: (a) small (leaf length, leaf width <11 cm), (b) intermediate (leaf length, leaf width 11–12 cm), (c) large (leaf length, leaf width>12); pod size group: (1) short (<6 cm long), (2) medium (6–7 cm) and (3) long (>7 cm); very early-flowering (40–50 days after planting); early-flowering (51–60 days); intermediate-flowering (61–80 days); late-flowering (91–110 days); very late-flowering (111–130 days) and extremely late-flowering (131–150 days). PI =Plant introduction number; TLN = Tropical lablab, Niger; BARSD = Bauchi State Integrated Rural Development Authority, Niger; Grif = Griffen, Georgia, USA; NAPRI = National Animal Production Research Institute, Nigeria; ILRI = International Livestock Research Institute, Ethiopia.

Table 4. Morphological (qualitative) grouping of lablab accessions.

Group 1	(White seeds, green leaves, green stems, white flowers and flat pods): Grif 1246.
Group 2	(White seeds, green leaves, green stems, white flowers and inflated pods): PI 164772, PI 183451, PI 288466, PI 288467, PI 388003, PI 542609, NAPRI 4, ILRI 4612, TLN 6 and TLN 13.
Group 3	(Brown seeds, green leaves, green stems, white flowers and inflated pods): PI 322531 and NAPRI 3.
Group 4	(Purple seeds, green leaves, green stems, white flowers and inflated pods): PI 195851, PI 388013, PI 596358, ILRI 730, ILRI 7403, BARSD 1, NAPRI 2 and TLN 9.
Group 5	(Purple seeds, green leaves, green stems, white flowers and flat pods): PI 345608, PI 509114 and PI532170.
Group 6	(Purple seeds, purple leaves, purple stems, purple flowers and inflated pods): PI 346440.
Group 7	(Green seeds, green leaves, green stems, white flowers and flat pods): PI 338341.
Group 8	(Black seeds, purple leaves, purple stems, purple flowers and flat pods): Grif 12293, Grif 969, PI 337534, PI 388019 and PI 439586.
Group 9	(Black seeds, green leaves, green stems, purple flowers and inflated pods): PI 164302, PI 387994, PI 401553, ILRI 147, ILRI 6930, ILRI 7279, TLN 7 and TLN 29.
Group 10	(Black seeds, green leaves, purple stems, purple flowers and inflated pods): PI 284802, PI 388012, PI 388017 and PI 388018.
Group 11	(Black seeds, green leaves, purple stems, purple flowers and flat pods): PI 392369, PI 416699 and PI 555670.

and later became white with the same inflorescence bearing both colours at the same time. Thirty-five accessions had bulging or inflated dry pods, while the remaining 11 produced flat pods.

Emergence, establishment and pod, grain, biomass, nodule and nitrogen production

Results of emergence, establishment and pod, grain, biomass, nodule and nitrogen production are summarised in Table 5. In general, while the very early to intermediate flowering groups performed better in the second year, the late to extremely late-flowering groups performed better in the first year, in terms of biomass yields and nodule numbers. Plant biomass and seed yields were inversely related. The late-flowering group with 6 accessions had the highest mean grain yield (2 t/ha), while the extremely late group, containing a single accession, had the lowest mean yield (0.6 t/ha). Maturity groups with low leaf:stem ratios had high leaf, stem and root dry matter yields, while those with high leaf:stem ratios had low leaf, stem and root dry matter yields. Higher dry matter yields were associated with late- to extremely late-flowering groups and lower dry matter yields with very early- to intermediate-flowering groups. Accessions belonging to the very late-flowering group had the highest N and root dry matter yields, while the very early-flowering group produced the lowest N and root dry matter yields.

Discussion

Variability

The study has highlighted the wide variation, which exists among lablab accessions. All accessions grew vigorously and set seed, suggesting that environmental factors did not markedly limit growth. It appears that excess P in Year 2 due to residual P and wet soil conditions due to excess rainfall from July-September caused reduced performance in the late- to extremely late-flowering groups. Since very early- to intermediate-flowering groups contain more P in their tissues (Hendricksen and Minson 1985; Ewansiha 2002) with light canopy cover, they were probably able to tolerate more P and wet soil conditions better than the remaining groups. It is not unlikely that harrowing in Year 1 improved soil water infiltration.

The very strong relationship between leaf and pod colour may be associated with anthocyanin metabolism that is being expressed in the whole plant. The associations between flower and seed colours are of interest. All accessions with purple flowers had black seeds while those with white flowers were associated with other seed colours. Those with cream or white seeds always had green stems, green leaves, green pods and white flowers as had been observed in cowpea (Summerfield *et al.* 1974), where white flowers were mainly associated with white or partly white seeds. Smartt (1985) mentioned that, in many pulses, white seeds were associated with white flowers, while pigmented seeds were associated with purplish flowers. Variability in flower and seed colour within one accession reported by Schaaffhausen (1963) and Holland and Mullen (1995) was confirmed, even though it is unlikely that the affected accessions in all the studies were the same. Variation in flower colour has also been reported in *Centrosema pascuorum* (Tarawali *et al.* 1999) and was interpreted as an indication of outcrossing. Phenological groupings appeared

Table 5. Emergence, establishment, grain yield, biomass yield and nitrogen yield of lablab accessions of different flowering groups.

Variable[1]	VE	E	I	L	VL	EL		
Number of accessions	7	20	4	6	8	1	Mean	s.e.
Emerg (days to 50%)								
2000	6	5	6	6	6	5	6	0.39
2001	6	6	6	6	6	5	6	0.39
Mean	6	6	6	6	6	5	6	0.28
Estab (%, 6 WAP)								
2000	76	81	73	86	81	88	80	3.5
2001	78	77	78	77	76	74	77	3.5
Mean	77	79	75	81	78	81	79	2.5
Pod (kg/ha)								
2000	1749	3232	2352	2817	1939	1306	2623	394.8
2001	1290	1730	2684	2835	2110	778	1953	394.8
Mean	1520	2481	2637	2891	2025	1042	2288	279.1
Seed (kg/ha)								
2000	1125	2108	1734	1859	1245	768	1711	274.5
2001	793	1074	1780	1938	1393	441	1258	274.5
Mean	959	1591	1759	1945	1319	604	1485	194.1
Leaf (kg/ha)								
2000	391	605	1365	2574	3580	2899	1436	248.4
2001	465	838	1549	1834	2045	1928	1209	248.4
Mean	428	721	1467	2164	2812	2414	1323	175.6
Stem (kg/ha)								
2000	219	325	1205	2406	4672	4509	1477	285.5
2001	243	452	1279	2056	2921	1340	1158	285.5
Mean	230	388	1246	2243	3796	2925	1318	201.9
Root (kg/ha)								
2000	43	56	109	159	224	229	104	23.8
2001	37	56	120	201	220	153	109	23.8
Mean	40	56	115	185	222	191	107	16.8
Leaf:stem ratio								
2000	1.88	2.05	1.21	1.08	0.79	0.61	1.58	0.27
2001	1.99	2.07	1.23	0.98	0.74	1.47	1.59	0.27
Mean	1.93	2.06	1.22	1.00	0.76	1.06	1.58	0.19
Nitrogen (kg/ha)								
2000	15	22	67	123	159	135	64.1	15.9
Total nodule (No/plant)								
2000	9	9	16	14	6	5	10	4.5
2001	21	18	20	14	6	12	16	4.5
Mean	15	13	18	14	6	9	13	3.2
Effective nodule (No/plant)								
2000	6	5	6	2	1	0	4	3.7
2001	19	16	15	11	2	0	13	3.7
Mean	12	11	11	6	1	0	9	2.6

[1]VE, very early-flowering group; E, early-flowering group; I, intermediate-flowering group; L, late-flowering group; VL, very late-flowering group; EL, extremely late-flowering group; Emerg, emergence; Estab, establishment; WAP, weeks after planting.

to be closely related to photoperiod (Table 6), which seems to confirm that photoperiod determines flowering in lablab (Schaaffhausen 1963).

Duplicate accessions

Most accessions in the same morpho-phenological group appeared to be the same genotype, although the original introductions came from different countries. For example, accessions ILRI 147, PI 387994 and PI 401553 (all equivalents of Highworth) belonged to the same group, suggesting that they are duplicates. Similar observations have been made previously (Wood 1983; Pengelly and Maass 2001). This finding will help to avoid unnecessary future testing of accessions, which are identical.

Very early-, early- and intermediate-flowering accessions

These accessions, which all flowered within 80 days, produced short plants and provided light

Table 6. Photoperiod and lablab phenology.

Flowering group	Flowering month (time to 50% flowering)	Photoperiod
Very early	August	12.35
Early	August	12.35
Intermediate	September	12.05
Late	October	11.73
Very late	November	11.47
Extremely late	November	11.47

soil cover, and may be unsuitable as cover crops for erosion control. They had more or less indeterminate plant growth with continued flowering and podding along with delayed leaf senescence, which prevented a single harvest. Maturing of pods during the rainy season pre-disposed the pods to rotting, especially for accessions with pods close to the ground. Most accessions had their pods buried within the canopy, making control of pod-boring insects with insecticide sprays difficult. Overall, accessions in these groups might be suited to areas with low rainfall or a short growing season, either as a sole crop or in mixture with appropriate cereals. However, 15 accessions with long or very long pods were identified as promising vegetable-type lablab because they had fleshy, succulent, broad or narrow pods. Lablab accessions with these pod characteristics are preferred as vegetables (Veeraswamy *et al.* 1973; Kay 1979; NAS 1979; Shivashankar and Kulkarni 1989b) and will provide farmers a wide range of material for use as a food crop for humans as well as a grain crop for livestock.

Late-, very late- and extremely late-flowering accessions

These accessions, which all flowered after 90 days, had faster and higher plant growth with characteristically short pods and large leaves, providing quick and effective soil cover for erosion and weed control. Accessions in these groups may be most useful in the wetter zones of the dry savanna. The pods are carried well above the canopy, making spraying with insecticide more effective, while there is little or no pod rot. Higher dry matter and N yields were produced, which would provide more available organic matter and N, when allowed to decay or worked into the soil as crop residues or green manure. Field observations during the trial showed that the woody stems decay quickly when buried along the furrows of previous ridges. As quantitative short day plants, through manipulation of planting date, these accessions could be made to grow bushier, having erect growth. Ripening of pods would become more uniform and the number of harvests reduced, although grain and fodder yields may be lowered.

Grain and dual-purpose accessions

Eleven accessions in Groups 1 and 2 (Table 4) had white seeds, which are reportedly preferred for grain-type lablab (Duke *et al.* 1981; Smartt 1985; Holland and Mullen 1995). These accessions range from low-growing to tall-growing plants and from indeterminate to more determinate types. While the early- and intermediate-flowering accessions with white seeds may serve as grain alternatives in areas where forages for livestock are not important, the late to very late accessions with large biomass may have potential for dual-purpose use as a feed-food source in the changing farming systems of the west African savanna. Since most of the white-seeded accessions are early-maturing, farmers will be able to harvest sufficient grain early in the season to replenish the depleted food reserves from the previous year. The reciprocal relationship between biomass and seed yields indicates that lablab is a low harvest index crop for the late- to extremely late-flowering groups.

Conclusion

This study provides information that appropriate lablab accessions can be identified for specific roles and zones. Duplicate accessions were identified, which will help to avoid the use of accessions with similar attributes when selecting plant materials for research and farmers' use. Studies that will enhance system integration for the dual-purpose accessions, identify appropriate planting times and plant populations for different maturity-types and investigate how to improve grain yields and the suitability of grains for human and animal consumption are warranted. Nutrient studies involving P to enhance production are needed.

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