Annual Report - 1987

(Comprehensive Research on Rice)

PROJECT TITLE: White Lupin as a Rotation Crop for Rice Growers: Yield Potential and Residual N Input from N_2 Fixation

STATUS OF PROPOSAL: New __X__ Continuing ____

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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OBJECTIVES:

1. To assess the suitability of white lupin as a rotation crop for California rice growers.

2. To quantify the yield potential of white lupin as related to planting date and maturity group (early or late genotypes) under field conditions.

3. To quantify the seed protein yield, crop N derived from N_2 fixation, and residual crop N returned to soil from crop residue incorporation as related to planting date for early and late genotypes to determine the potential N input to a subsequent rice crop.

Two field experiments were established at the UC Davis Field Research Facility during October/November 1986. In Experiment I, the effects of planting date on yield was assessed for early and late maturity lupin cultivars. The experiment employed a split plot, randomized block design with four replications. Planting dates (October 6, October 18, October 29, and November 10) were mainplot treatments with the two lupin cultivars and nonlegume N reference crop (triticale) as subplots. Plant density for all lupin treatments was measured at 1 month, 2 months, and 3 months after planting. Plant dry matter yield was measured at full-flowering stage and at maturity. In the final harvest at maturity, seed yield and crop residue dry matter yield (including stems, leaves, and pods) was measured and subsamples taken for N analysis. At both the flowering and final maturity sample dates, a comparable dry matter yield sample was taken in triticale plots which will also be processed for N analysis. Lupin total N yield and partitioned seed and crop residue N will be calculated. The quantity of N derived from symbiotic N_2 fixation will be estimated by subtracting the N uptake found in the triticale crop from that measured in the lupin crop (i.e., the N difference method). No N fertilizer was applied to the lupin or triticale plots.

In Experiment 2 four high yielding lupin genotypes (2 short season and 2 later maturing lines) were grown with inoculation with Rhizobium, without inoculation with Rhizobium, and with 250 lb N/ac but without inoculation with Rhizobium. The lupin cultivar and Rhizobium or N fertilizer treatments were established in a randomized complete block design with four replications. The experiment was planted on October 25, 1986. A triticale nonlegume reference treatment was also included to assess the native soil N-supplying capacity without N fertilizer. Similar measurements were made in this study as in Experiment 1.

Summary of 1987 Research Accomplishments

Objectives 1 and 2:

The suitability of white lupin as a rotation crop for rice in the Sacramento Valley will depend primarily on the flexibility in time of planting and economic returns as compared with other rotation crops. The latest optimal planting date will determine how much time growers would have for lupin seedbed preparation after rice harvest while the economics of lupin production will primarily reflect seed yield since our results show that no N fertilizer is required and irrigation needs are similar to wheat. Thus lupin production costs may be somewhat lower than for wheat.

Data from the planting date study show that lupin seed yields were highest when sowing occurred in late October or early November (Table 1). Yield of the early maturing 'Ultra' was less influenced by planting date than yield of the later maturing 'Multolupa'. When planted on 29 October or 10 November Multolupa seed yield averaged 5880 kg ha^{-1} (5250 lb/acre) which was 20% greater than for the earlier maturing 'Ultra' from equivalent planting dates.

Seed yield of the five cultivars tested in a separate field experiment planted 26 October ranged from 4816 kg ha^{-1} to 5191 kg ha^{-1} (4300 to 4635 lb/acre, Table 2). In general, yields were lower in 1986/87 than in 1985/86 (Table 3) and most likely this resulted from the extended heat wave in May 1987 (8 consecutive days with temperatures above 90 F) which appeared to cause flower abortion on secondary racemes. In both years, however, the cultivar 'Hamburg' had the highest seed yield: 6209 and 5191 kg ha^{-1} in 1985/86 and 1986/87, respectively.

It is our belief that a 5000 lb/acre seed yield is an attainable average field-scale yield for this crop with a cultivar such as 'Hamburg'. Assuming a price of $150/ton (estimated by the feed purchasing department at Foster Farms, Inc.) this would provide a gross return of $375/ac. By contrast, a 7000 lb/ac wheat crop at $100/ton would give a gross value of $350/ac but would require at least 100 lb N/ac and, with either 'Anza' or 'Yolo' cultivars, would not meet bread-quality protein standards.

Objective 3:

In both 1985/86 and in 1986/87 lupin seed yield was not influenced by inoculation with Rhizobium or high rates of N fertilization (Tables 4 and 5, respectively). However, seed N concentration, total seed N (i.e., protein) and total crop N were significantly reduced without inoculation or N fertilizer in 1985/86 (Table 4). Comparison of inoculated treatments with treatments receiving 200 kg N fertilizer ha^{-1} clearly shows that symbiotic N fixation by the lupin crop provides adequate N nutrition and that use of N fertilizer is not required on this crop. Thus, rhizobium inoculum which costs about $4/acre would replace the 100-200 lb N/acre required to grow bread quality wheat. Plant N analyses are not yet finished for the 1986/87 study.

The results from the 1985/86 experiments show that seed N concentration of inoculated lupin range from 4.9 to 5.6% (i.e, 31 to 35% protein) and this is approximately 80 to 85% that of soybean (Table 6). On a whole plant basis, the total N yield of the late maturing cultivars averaged 333 kg N ha^{-1} (297 lb N/acre) and was about 10% lower for the two best early maturing cultivars. Total aboveground dry matter yield averaged 14500 kg ha^{-1} (12925 lb/acre) for late maturing cultivars and had a N concentration of 2.3% (i.e, 14.4% protein). Thus, lupin may also be economically viable as a winter legume silage crop.

Nitrogen fixation by the lupin crop was estimated by the N difference method using rape or triticale as the nonlegume reference crop in 1985/86 and 1986/87, respectively. Since plant N analyses are not yet completed for the 1986/87 studies, only results from the 1985/86 are presented. Total crop N derived from N_2 fixation ranged from 135 to 250 kg N ha^{-1} (120 to 225 lb N/acre) for the seven cultivars tested (Table 7). However, the efficient partitioning of plant N to seed results in a net removal of about 55 kg N ha^{-1} (49 lb N/acre) by late maturing cultivars and 70 kg N/ha (63 lb N/acre) by early maturing cultivars if seed is harvested. Thus, the data suggest that there would be no net N input to soil if seed were harvested. By comparison, net N export of soil N with a 6500 lb grain/acre wheat crop would be about 75 lb N/acre and this would occur even after N fertilization of 120 lb N/acre.

Publications

Kevin Larson, the graduate student involved in these lupin studies, has just completed his M.Sc. thesis based on the 1985/86 field experiments. All plant N analyses from the 1986/87 studies will be completed by 31 December 1987 and we plan to submit papers based on the 2-year study to both the Agronomy Journal and California Agriculture early in 1988.

Summary

Optimal lupin planting date appears to be very similar to that of wheat in the Sacramento Valley and seed yield of the best variety, 'Hamburg', averaged 5700 kg ha^{-1} (5100 lb/ac) in the 1985/86 and 1986/87 field experiments in relatively large plots. Maximum lupin seed yields are obtained without N fertilizer and inoculation with Rhizobium increases seed protein and total crop N yield. Estimated symbiotic N_2 fixation was over 250 kg N ha^{-1} (225 lb N/acre) for the most promising cultivar. Efficient partitioning of total plant N to seed would result in a removal of 300 kg N ha^{-1} with seed harvest and a return of only 45 kg N ha^{-1} with incorporated crop residue. Thus there would be no net N input to soil after seed harvest. By contrast, N recycled to soil by straw incorporation from a 6500 lb grain/acre wheat crop would be nearly equivalent to N recycled in lupin residue after seed removal but N fertilizer rates of 100-200 lb N/acre would be required on the wheat crop while no N fertilizer is needed for lupin. Field-scale yield potential for lupin seed yield is estimated at 5000 lb/ac and gross returns would exceed that from a 7000 lb/ac wheat crop. I am optimistic that lupin would be competitive with wheat as a rotation crop for rice on the better-drained rice soils in the Sacramento Valley.

Table 1. Seed yield from four planting dates of two irrigated white lupin cultivars inoculated with Rhizobium lupini, UC Davis, 1986/87.

Cultivar	Seed yield*				Cultivar mean
	6 Oct	18 Oct	29 Oct	10 Nov	
Multolupa	4496	5078	5886	5873	5333
Ultra	4614	4855	4873	4913	4814
Planting date mean	4555	4967	5380	5393	
LSD 5% (planting date)		469			
LSD 5% (genotype)					446

* Seed yield reported at 12% moisture content.

Table 2. Seed yield and seed harvest index (SHI) of five irrigated white lupin cultivars inoculated with Rhizobium lupini, UC Davis, 1986/87.

Cultivar	Seed yield*	SHI+
Late maturing		
Hamburg	5191 a	42.3 c
Multolupa	4519 bc	37.9 c
Early maturing		
Buttercup	4972 ab	48.6 a
Kievskij	4816 ab	42.5 b
Ultra	4873 ab	44.9 ab
LSD 5%	474	4.4
CV %	7	7

* Seed yield reported at 12% moisture content.

+ Seed harvest index based on oven-dry yields.

Table 3. Days to maturity, mean yield and harvest index of white lupin cultivars inoculated with Rhizobium.

Cultivar	Days to Maturity	Mean Yield+	Harvest Index
		kg/ha	%
Late maturing			
Hamburg	227	6209 a++	38.42 c
Sparta	230	6047 a	38.38 c
Multolupa	232	5739 a	37.60 c
Carstens	230	5422 ab	34.96 C
Early maturing			
Minn. Ultra	218	5720 a	43.93 b
Buttercup	218	5713 a	48.80 a
Kievskij	216	4764 b	48.37 a
LSD 5%		865	4.35
CV		10.3	7.2

+ Yields are corrected to 12% moisture content.

++ LSD rating: yields with the same letter are not significantly different at $P < 0.05$..

Table 4. Yield and N content of seed, haulm, and whole plants for two white lupin cultivars as affected by inoculation with <u>Rhizobium lupini</u> (+I = with inoculation, -I = without inoculation) and N fertilization (+N = 200 kg N ha^{-1}, -N = no N fertilization), UC Davis, 1985/86.

Cultivar	Treatment	Seed			Haulm			Whole plant	
		Yield+	N concentration	Total N	Yield+	N concentration	Total N	Dry matter yield	Total N
		kg ha^{-1}	g N kg^{-1}	kg ha^{-1}	kg ha^{-1}	g N kg^{-1}	kg ha^{-1}	----- kg ha^{-1}	---
Multolupa	+I,-N	5739	53.4 a	274 a	10082 a	5.3 ab	58 a	15436 a	345 a
	-I,+N	5634	54.7 a	276 a	9204 a	5.6 a	52 a	14235 a	328 ab
	-I,-N	5531	52.9 ab	262 ab	7375 b	4.8 bc	35 b	12314 b	297 bc
Ultra	+I,-N	5720	50.6 bc	260 ab	6518 bc	4.0 d	26 c	11626 bc	286 cd
	-I,+N	5235	49.2 c	230 bc	5812 cd	4.0 d	24 cd	10485 c	254 de
	-I,-N	5448	45.2 d	220 c	5447 d	3.5 d	19 d	10311 c	239 e
LSD 5%		NS	2.3	37	920	0.8	6	1401	36
CV %		8	3	10	9	12	12	8	8

+ Seed yield reported at 12% moisture content. Haulm and whole plant dry matter yield are given on an oven-dried basis.

Table 5. Seed yield and seed harvest index (SHI) of five irrigated white lupin cultivars as affected by inoculation with <u>Rhizobium lupini</u> (+I = with inoculation, -I = without inoculation) and N fertilization (+N = 200 kg N ha^{-1}, -N = no N fertilization), UC Davis, 1986/87.

Cultivar	Treatment	Seed yield[+]	SHI[++]
<u>Late maturing</u>			
Hamburg	+I,-N	5191	42.3
Hamburg	-I,+N	4566	45.5
Hamburg	-I,-N	5075	47.3
Multolupa	+I,-N	4519	37.9
Multolupa	-I,+N	4457	37.6
Multolupa	-I,-N	4582	43.0
<u>Early maturing</u>			
Buttercup	+I,-N	4972	48.6
Buttercup	-I,+N	4569	43.9
Buttercup	-I,-N	4534	52.0
LSD 5%		618	3.3
CV %		9	5

Table 6. Yield and N content of seed, haulm, and whole plants for seven white lupin cultivars inoculated with Rhizobium lupini, UC Davis, 1985/86.

Cultivar	Seed			Haulm			Whole plant	
	Yield+	N concentration	Total N	Yield+	N concentration	Total N	Dry matter yield+	Total N
	kg ha^{-1}	g N/kg	kg ha^{-1}	kg ha^{-1}	g N/kg	kg ha^{-1}	----- kg ha^{-1}	----
Late maturing								
Hamburg	6209 a	54.7 ab	303 a	8883 a	4.9	43 b	14427 a	347 a
Sparta	6047 a	53.1 abc	286 ab	8698 a	4.5	40 b	14097 a	326 ab
Multolupa	5739 a	53.4 abc	274 ab	10082 a	5.3	58 a	15436 a	345 a
Carstens	5422 ab	55.9 a	269 ab	9088 a	4.7	43 b	13929 a	312 ab
Early maturing								
Ultra	5720 a	50.6 cd	260 b	6518 b	4.0	26 c	11626 b	286 b
Buttercup	5713 a	51.9 bc	265 ab	5457 bc	4.7	25 c	10459 bc	290 b
Kievskij	4764 b	48.5 d	207 c	4679 c	4.2	20 c	8933 c	227 c
LSD 5%	865	3.2	41	1513	NS	10	2035	41
CV %	10	4	10	14	15	19	11	9

+ Seed yield reported at 12% moisture content. Haulm and whole plant dry matter yield are given on an oven-dried basis.

Table 7. Nitrogen input/output budget for seven irrigated white lupin cultivars based on seed harvest and return of haulms, UC Davis, 1985/86.

Cultivar	Whole plant			Seed	Net N++
	Total N	N from soil+	N from N_2 fixation	Seed N	Net N++ removed with seed
	---------- kg ha^{-1} ----------				
Late maturing					
Hamburg	347 a	96	250 a	303 a	53 b
Sparta	326 ab	97	229 ab	286 ab	58 b
Multolupa	345 a	98	247 a	274 ab	40 c
Carstens	312 ab	97	215 ab	269 ab	55 b
Early maturing					
Ultra	286 b	93	193 b	260 b	68 a
Buttercup	290 b	93	197 b	265 ab	68 a
Kievskij	227 c	93	135 c	207 c	73 a
LSD 5%	41		41	41	10
CV %	9		13	10	12

+ Estimated from total N uptake by the nonlegume reference crop, *Brassica napus* L. for an equivalent duration of active growth.

++ Represents the difference between seed N yield and the estimated quantity of N derived from N_2 fixation.