Station Bulletin 513 1975

PULSE OR GRAIN LEGUME CROPS FOR MINNESOTA

R.G. Robinson

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

PREFACE—In a world concerned with shortages, of food, energy, and nitrogen, increasing numbers of urban and rural people want to develop a life style based on natural foods, low consumption of manufactured products, and self sufficient food production. Pulse crops are a very important part of this movement, and reliable information is needed. Pulses are a group of crops analogous to other major groupings such as grain, forage, vegetable, fruit, and sugar crops. This bulletin gives a comprehensive classification of the kinds of pulses, their relationships, their adaptation in Minnesota, and how to grow them.

CONTENTS PAGE

R. G. Robinson is a professor, Department of Agronomy and Plant Genetics, University of Minnesota.

Regulations and suggestions for the use of chemicals in this bulletin are subject to change. Some products and procedures may become illegal or obsolete; new products and procedures may be approved. It is the responsibility of each user of agricultural chemicals to follow directions on the manufacturer's label and to be familiar with current regulations. Use of commercial names does not imply endorsement nor does failure to mention a name imply criticism.

PULSE OR GRAIN LEGUME CROPS FOR MINNESOTA

R.G. Robinson

Pulse crops belong to the legume family of plants. Their seed is used for human food and livestock feed. They occupy more than 160 million acres of the world's cropland and are exceeded only by wheat, corn, rice, and barley in harvested acreage. The nine major groups of pulse crops in world acreage are dry bean, chickpea, field pea, cowpea, fababean, pigeon pea, vetch, lentil, and lupine (table 1). Soybeans and peanuts are often used as pulse crops, but their major uses are for oil and the protein meal remaining after oil extraction, so they are classified as oilseed crops.

The leading countries in pulse production tend to be either developing countries or countries of high population. Pulses provide 27 percent, 23 percent, and less than 5 percent of the food protein consumed in India, Brazil, and the United States, respectively. When the United States was a developing country, pulses were relatively more important than now. For example, beans and peas occupied 12 percent of Minnesota cropland in 1850 but now account for less than 1 percent.

Nutritional and Storage Aspects

Pulse crops have a unique combination of advantages for human food and livestock feed. The seeds contain more protein than needed for human nutrition in contrast to grain crops, which lack sufficient protein. Furthermore, pulse protein is relatively high in the lysine and tryptophan amino acids that are usually low in grain crops. Consequently, pulses in the diet supplement the low percentages of protein present in foods made from grain crops.

One ounce of dry pulse seed has an energy value of about 95 calories. The dry seed is about 60 percent carbohydrate (including 5 percent fiber), 24 percent protein, 3 percent minerals, 1 percent fat, and 12 percent water.[1] Pulses and wheat are about the same in caloric value, but pulses are higher in protein, minerals, and fiber and lower in carbohydrates and fat.

Pulse protein is less digestible than that of wheat, meat, eggs, and milk and has a less desirable amino acid composition for human nutrition than eggs, meat, and milk. The sulfur containing amino acids methionine and cystine are the limiting constituents of pulse protein. Despite this drawback, ⅔ pound of pulse seed meets the U.S. Food and Nutrition Board's recommended daily protein needs for an adult human, including all essential amino acids.

Consumption of large amounts of some pulses, particularly dry beans, makes some people uncomfortable because of flatulence. Raffinose and stachyose sugars from the bean carbohydrate are digested by microorganisms in the human intestine, and gas is liberated. Countries and individuals that depend on pulses for their major source of protein tend to use chickpea, field pea, fababean, and lentil alternatives to some dry beans to partially avoid this problem. Native methods of food preparation including additives and sprouting are also reported effective in reducing flatulence problems.

Mature seeds of most pulses contain toxic or growth retarding substances of various kinds. Some of these substances inhibit protein digestion and develop as the seed approaches maturity, thus allowing storage of protein in the seed. The toxicity problem is not serious with most pulses used for human food because normal food preparation, including heating, destroys the harmful materials. Roasting or other special treatment should be considered when certain pulses are fed to nonruminant (swine, poultry) livestock. Field peas have fewer harmful substances than most other pulses.

Alkaloids that impart a bitter taste are removed from lupine by alternate soaking and boiling. Alkaloid-free varieties of lupine have been developed.

Lathyrism disease is found in countries where people eat large amounts of grass pea. Some individuals among the races and nationalities surrounding the Mediterranean have a genetic tendency to develop favism disease from eating large amounts of fababeans. Favism disease is unknown, however, among other races and nationalities that consume large amounts of fababeans.

Pulse seeds will keep for many years in dry storage and can be processed for food in the home. Consequently, pulses are compatible with the subsistence type of agriculture needed in developing countries. Furthermore, in-

[1]Averages. Species and varieties and the environment in which they are grown affect the composition of pulse crops.

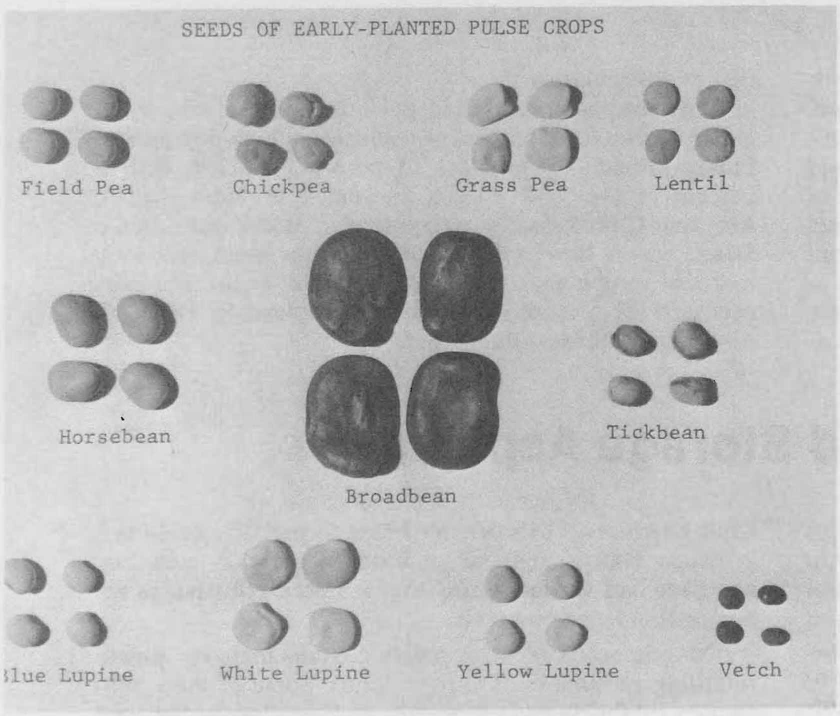


Figure 1. Seeds of cool weather pulse crops. Considerable variation occurs among different varieties of each pulse.

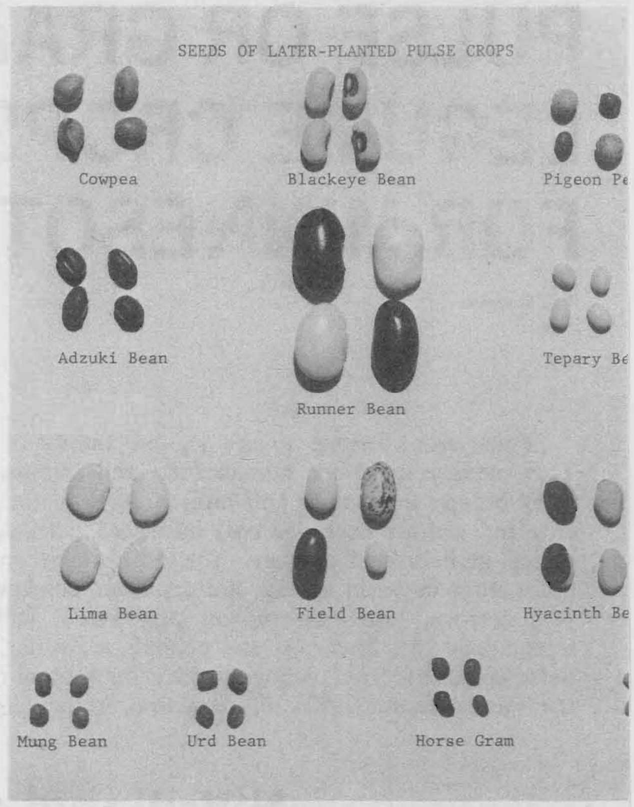


Figure 2. Seeds of warm weather pulse crops. Considerable variation occurs among different varieties of each pulse.

Figure 3. Seeds of market classes of field beans.

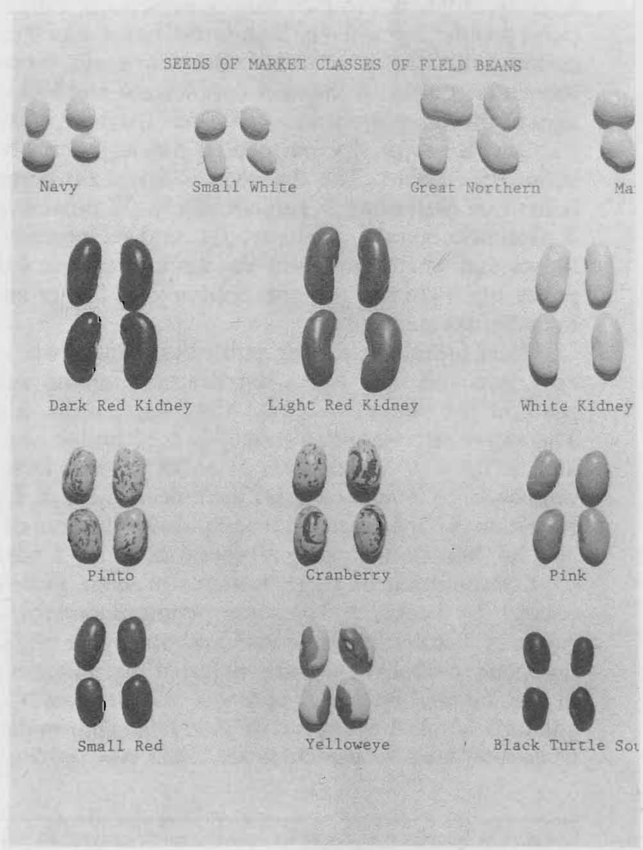


Figure 4. Gastro, a short, early field pea variety (left) and Century, a tall variety (right) grown on sandy soil without irrigation. Field peas lodge before seed is mature. Spring sown winter wheat borders help separate the plots of prostrate pea vines.

creasing numbers of Americans are expressing interest in natural foods, self sufficiency, and elimination of middlemen between producer and consumer. Pulses are a basic commodity for these people.

The same characteristics that make pulses valuable food crops for subsistence farms make them valuable feed crops for livestock farms. Farmers using pulse crops as carbohydrate and protein concentrate feeds can reduce or eliminate cash purchases of urea, anhydrous ammonia, and protein meals commonly used as protein concentrates.

Adaptation in Minnesota

The major and some of the minor pulse crops of the world (table 1) have been tested at Rosemount, Elk River, or other experiment stations in Minnesota. A major objective of this research was to find crops with high protein seed that could be used by livestock farmers as homegrown protein concentrates. Although forage crops such as alfalfa fill some protein needs, farmers purchase protein concentrates of crop, livestock, or industrial origin. Those of Minnesota crop origin are the meals remaining after oil extraction from soybean, flax, and sunflower seed. Those of livestock origin include meat, fish, and dairy products such as tankage, fishmeal, and dried skim milk. Those of industrial origin include urea and anhydrous ammonia, which supply nitrogen in a form that cattle can convert to protein. In contrast to these concentrates of industrial origin, which supply only nitrogen, pulses are also a high energy feed.

PERFORMANCE OF EARLY SOWN (APRIL) PULSE CROPS

Pulses can be divided into crops of warm and cool season adaptation. Those of cool season adaptation are often grown as winter crops in tropic to temperate regions and as early spring sown crops in northern regions. None of the crops in table 1 will survive Minnesota winters without the use of uneconomic methods such as mulching. But field pea,[2] fababean, lentil, lupine, common vetch, chickpea, and grass pea are resistant to frost and should be sown at the beginning of field work in the spring. Planting dates in the years reported in table 2 ranged from March 22 to April 17 at Elk River and from April 15 to April 25 at Rosemount. Large plots replicated three times were planted, sprayed, and harvested with standard farm machinery except at Elk River, where plots were harvested and threshed with plot equipment. All crops were sown with a grain drill in rows 6 inches apart. Plots for pulse crops were sprayed before planting with trifluralin (Treflan) at 1 pound per acre on silt loam soil at Rosemount and ½ pound per acre on sandy soil at Elk River for control of grass and some nongrass annual weeds. Oats were sprayed postemergence with a mixture of dicamba (Banvel) at ⅛ pound per acre plus MCPA at ¼ pound per acre to control nongrass weeds.

Oats yielded more than the pulse crops at Rosemount, but the pulses were much higher in protein. All pulse

[2]Field pea varieties have smooth seeds and vary in blossom and seed color. Varieties with cream or green colored seed are used for food in the United States, but varieties of other colors are used for feed. Canning or garden varieties have green, wrinkled seed when mature, but they are harvested for vegetable use when they are immature, sweet, and tender. Alaska and related varieties are exceptions because they have smooth green seeds at maturity and are used either as a field or canning pea. Edible pod peas (sugar peas, snow peas) are also *Pisum sativum*, but the pods with very immature seed are consumed as a vegetable like snap beans. The varieties used have stringless, nonwoody pods at this early stage of seed development.

Table 1. Pulse crops of the world and their adaptation in Minnesota

Common name	Scientific name	Countries leading in acreage grown	Adaptation in Minnesota
	NINE MAJOR GROUPS OF PULSE CROPS ARRANGED IN ORDER OF ACREAGE		
Dry bean		India, Brazil, China, Mexico	
Field bean (common bean)	*Phaseolus vulgaris* L.		Field crop
Lima bean	*Phaseolus lunatus* L.		Canning crop
Tepary bean	*Phaseolus acutifolius* A. Gray		Garden crop
Runner bean	*Phaseolus coccineus* L.		Garden crop
Blackeye bean	*Vigna unguiculata* (L.) Walp.		Too late maturing
Adzuki bean	*Vigna angularis* (Willd.) Ohwi & Ohashi		Field crop potential
Mung bean (green or golden gram)	*Vigna radiata* (L.) Wilczek		Garden crop
Chickpea (garbanzo, Bengal gram)	*Cicer arietinum* L.	India, Pakistan, Ethiopia, Mexico	Garden crop
Field pea (dry pea, English pea)	*Pisum sativum* L.	China, USSR, India	Field crop
Cowpea (southern pea)	*Vigna unguiculata* (L.) Walp.	Nigeria, Upper Volta	Too late maturing
Fababean	*Vicia faba* L.	China, Italy, Morocco, Brazil	
Broadbean	*Vicia faba* L. var. *major* (Alef.)		Garden crop
Horsebean	*Vicia faba* L. var. *equina* (Pers.)		Field crop potential
Tickbean (pigeon bean)	*Vicia faba* L. var. *minor* (Beck)		Field crop potential
Pigeon pea (red gram)	*Cajanus cajan* (L.) Millsp.	India	Too late maturing
Vetch		USSR, Turkey	
Common vetch (tares)	*Vicia sativa* L.		Field crop potential
Lentil	*Lens culinaris* Medikus	India, Ethiopia, Syria, Turkey	Field crop potential
Lupine		USSR, South Africa, Poland	Field crop potential
Blue lupine	*Lupinus angustifolius* L.		Disease problem
Yellow lupine	*Lupinus luteus* L.		Disease problem
White lupine	*Lupinus albus* L.		Disease problem
	MINOR PULSE CROPS		
Urd bean (black gram)	*Vigna mungo* (L.) Hepper	India	Too late maturing
Horse gram	*Dolichos biflorus* L.	India	Too late maturing
Hyacinth bean (Bonavist, Egyptian bean)	*Dolichos lablab* L.	India	Too late maturing
Grass pea (chickling vetch)	*Lathyrus sativus* L.	India, Pakistan	Toxicity problem
Guar (cluster bean)	*Cyamopsis tetragonoloba* (L.) Taub.	India	Too late maturing

crops except common vetch produced more protein per acre than did oats. Gela lupine was the highest yielding pulse, followed by peas, tickbean, horsebean, and lentil at Rosemount. On the Elk River sand, peas were highest in yield, and both tickbean and horsebean yielded considerably less than lupine. Lentil and vetch yielded the least at both locations. Of the pulse crops shown in table 2, the fababeans—horsebean and tickbean—are the least adapted to droughty sandy soil. Broadbean is similar to the other fababeans in adaptation but it yields more. The extremely large seed of broadbean does not plant evenly through a standard grain drill, and seed cost per acre is high.

The maturity dates in table 2 indicate that these pulses require about the same length of growing season as wheat. Fababeans are particularly sensitive to damage from hot, dry weather and must be planted early or the seed crop will fail. The other pulses have more tolerance to late planting, but early planting is best.

Lupine seed has the highest protein percentage of the pulses shown in table 2. Many varieties of blue, yellow, and white lupine were tested, and the crop was found to have excellent field crop potential. The most yield-limiting factor is a root rot disease caused by *Rhizoctonia solani* Kuehn. Gela is the only variety tested that yields well; others look good, but seed yield is poor because of disease. The disease also occurred on plots in southwestern Minnesota and in 1975 injured Gela in northern Minnesota. The second problem with lupine is alkaloids. Gela was originally low alkaloid but needs reselection for this characteristic. New low alkaloid varieties from Australia are also disease susceptible. Plant breeding is needed to make lupine a good crop for Minnesota.

Weeds are the limiting factor in lentil production because the crop is too short to compete strongly with weeds. Herbicides approved for lentil will control only a few of the important weed problems. Large increases in lentil acreage in Minnesota probably depend on further weed control research and Environmental Protection Agency (EPA) approval of wider spectrum herbicides. Lack of approved herbicides is also a limiting factor in expansion of fababean acreage.

Table 2. Comparison of early sown pulse crops and oats on silt loam soil at Rosemount and on sandy soil at Elk River

Crop and variety	Years tested[1]	Seed sown/acre, pounds	Mature date	Height, inches	Lodging score[2]	Weed control, percent	Seed protein, percent[3]	Seed yield/acre, pounds
ROSEMOUNT, WITH NO IRRIGATION								
Oat, Lodi	1970-74	76	7-24	49	4	96	13.8	2,548
Horsebean	1970-74	172	7-31	44	3	88	29.1	1,975
Tickbean, Petite	1971-74	179	7-25	26	3	79	29.8	2,042
Field pea, Century	1972-74	210	7-23	55	9	100	25.8	2,133
White lupine, Gela	1972-74	221	8-10	35	1	81	34.4	2,278
Lentil, Tekoa	1973-74	80	7-24	21	7	71	25.5	1,348
Common vetch, Warrior	1971-72	73	7-25	36	9	63	—	995
LSD 5 percent						5		118
ELK RIVER, IRRIGATED WITH 8 INCHES OF WATER PER YEAR								
Horsebean	1973-74	172	7-30	33	2	100	26.5	1,594
Tickbean, Petite	1972	180	7-30	25	2	100	25.8	1,048
Field pea, Century	1972-74	215	7-23	55	9	100	25.0	2,567
White lupine, Gela	1972-74	217	8-9	30	2	100	34.8	1,891
Lentil, Tekoa	1973-74	80	8-3	18	—	100	24.0	865
Common vetch, Warrior	1972	73	7-22	21	9	100	27.3	634
LSD 5 percent								248
ELK RIVER, WITH NO IRRIGATION								
Horsebean	1973-74	172	7-29	24	1	100	25.8	722
Tickbean, Petite	1972	180	7-25	20	1	100	24.8	770
Field pea, Century	1972-74	215	7-18	39	9	100	23.0	1,716
White lupine, Gela	1972-74	217	8-1	22	2	100	32.9	1,237
Lentil, Tekoa	1973-74	80	7-19	16	—	100	23.8	656
Common vetch, Warrior	1972	73	7-17	19	9	100	24.5	515
LSD 5 percent								248

[1] Data for crops not grown in all years are adjusted to be comparable with 5-year data at Rosemount and 3-year data at Elk River.
[2] 1 erect, 9 flat.
[3] Oven-dry basis.

Root rots caused by *Rhizoctonia* and *Fusarium* species greatly reduced yields of lentil seed in some trial plots.

Although common vetch is used as a pulse in other countries, the major purpose of production in Minnesota is to sell seed for forage planting uses. A different species, hairy vetch (*Vicia villosa* Roth), has been planted in the fall with winter rye on a few Minnesota farms for the forage seed market. It now grows wild in many sandy areas of eastern Minnesota.

Chickpeas produce an erect bush about 1½ to 2 feet tall. Neither yield nor seed quality of the strains tested was satisfactory in trials at Rosemount and in northern Minnesota.

Grass peas produce a vine about 3½ feet long. Some collections were excellent yielders at Rosemount, but the best strain was analyzed and found toxic. Nonetheless, *Lathyrus* species are important pulse crops in India and the Middle East. Moderate rather than excessive use evidently prevents common occurrence of lathyrism disease.[3]

PERFORMANCE OF LATE SOWN (MAY 15 TO JUNE 15) PULSE CROPS

Pulse crops for late sowing include dry beans, cowpea, pigeon pea, adzuki bean, mung bean, urd bean, horse gram, hyacinth bean, and guar. Those of greatest field crop potential in Minnesota are field and adzuki beans.

The market classes of field beans[4] are: navy (pea bean), pinto, pink, dark red kidney, light red kidney, white kidney, great northern, small white, flat small white, cranberry, yelloweye, marrow, small red, black turtle soup, and miscellaneous. All of these classes can be grown in Minnesota, but they differ greatly in yield and other characteristics. Each class includes one or more varieties. Varieties within a class are similar in seed size and color, but they may differ in yield, maturity, disease tolerance, and growth form. Growth forms range from prostrate vines to erect bushes. Among currently available varieties, those with large vines generally outyield those of bush type.

[3] Lathyrism became serious in Spain during World War II because of the large consumption of grass peas. Families consuming less than ½ pound per day remained healthy, but those who regularly consumed more than 1 pound per day contracted the disease.

[4] Snap beans and horticultural beans are also *Phaseolus vulgaris*. Plant breeders have developed snap bean varieties with thick walled, stringless pods. These pods, containing immature seeds, are used primarily as a vegetable not a pulse. Horticultural beans are often called shell beans. The seeds are usually harvested and threshed when mature but not dry. When harvested dry, they are placed in the appropriate class of field beans based on their seed characteristics. Many have the splashed red color markings of the cranberry class.

Figure 5. Early planted pulses sown in noncultivated rows 6 or 7 inches apart usually yield more than those planted in wide rows for cultivation. The first cultivated horsebean row was sprayed experimentally with TIBA growth regulator, which caused stem bending.

Figure 6. Fababean plants in early bud stage.

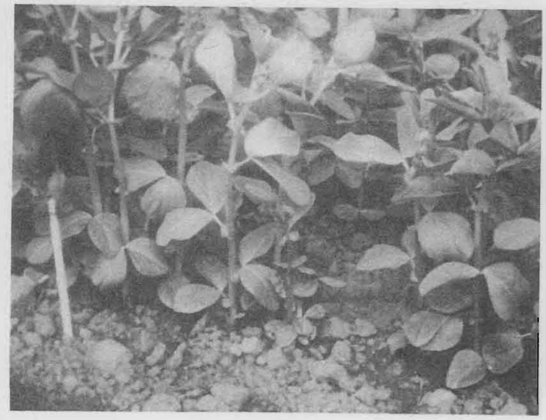


Figure 7. Yellow lupine in full pod stage.

Figure 8 (above). Vetch at the right and field peas at the left of an agronomy student from Ethiopia, where pulses are important crops.

Figure 10 (below). A white flowered, short vined grass pea variety in full bloom.

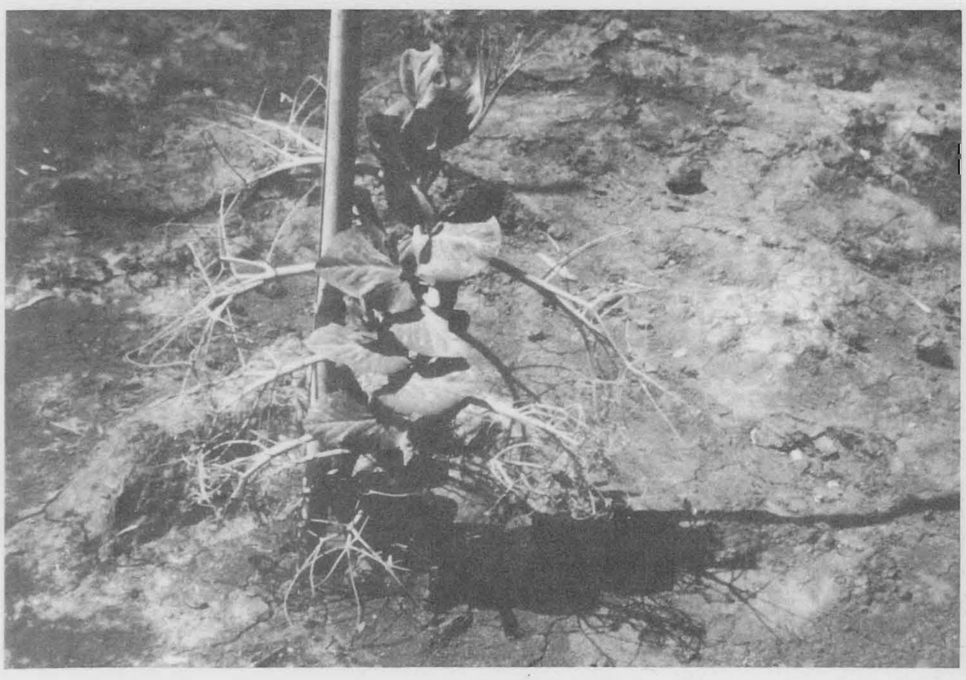
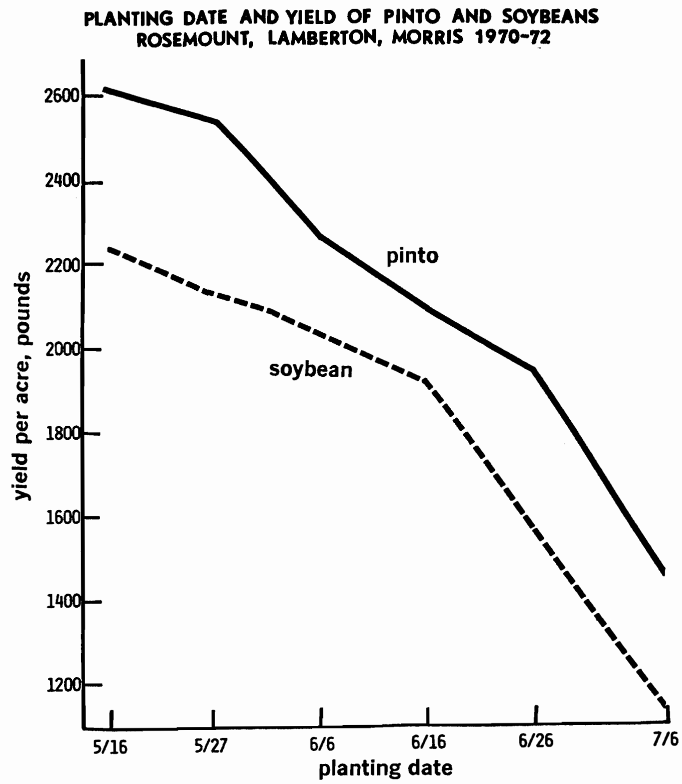
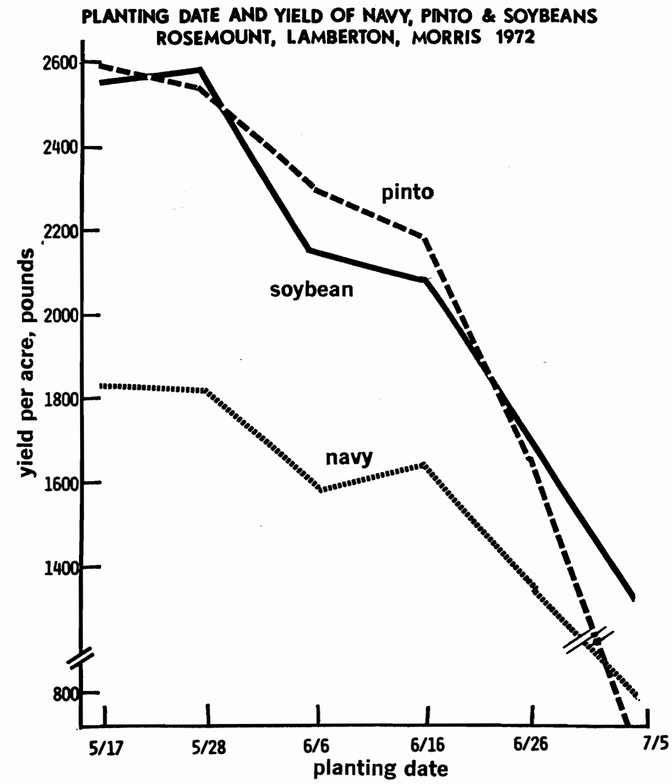


Figure 9. The field pea leaf is pinnately compound, with two large stipules at the base plus one or more pairs of leaflets along the extended petiole (midrib, rachis). The leaf terminates in tendrils. The pea plant in the photograph is one type of "leafless" pea; the leaflets have been replaced by tendrils and the stipules remain. Field peas have tendrils; field beans do not, so field bean vines climb by stem twining.

Figure 11. A white flowered bush chickpea variety.





Figures 12-13. Comparative yields of UI 114 pinto beans, Seafarer navy beans, and recommended varieties of soybeans planted at various dates from mid-May to early July. (Acknowledgement is made to Southwest Experiment Station superintendent W. W. Nelson and to West Central Experiment Station agronomist D. D. Warnes for supervision of field work at Lamberton and Morris, respectively.)

Varietal trial data are published annually in Agricultural Experiment Station Miscellaneous Report 24, *Varietal Trials of Farm Crops*. Certain varieties of the pinto, great northern, pink, and small red classes have tended to yield more than the other market classes of field beans. However, relative maturity, disease tolerance, growth form, market price, quality requirements, and yield should be considered in choosing a market class and variety.

The best varieties of field beans compare favorably in yield with the recommended varieties of soybeans on silt loam soil in southern Minnesota (figures 12 and 13). A similar relationship prevailed on irrigated and dryland sandy soil at Elk River with 1971-74 average yields of pinto highest at 1,993 pounds per acre, soybeans at 1,825 pounds per acre, and navy at 1,558 pounds per acre. On the dryland plots, however, soybeans outyielded pinto by 105 pounds per acre.

Adzuki beans produce late maturing, erect bush plants. The best strain tested had red seed and in 6 years of trial yielded about the same as navy beans but matured 3 weeks later.

Tepary beans are slightly smaller than navy beans and yielded 1,678 pounds per acre compared with navy at 2,433 pounds. There is no large commercial market for them.

Mung bean varieties have been selected to germinate very quickly because they are eaten as young bean sprouts. They are among the smallest seeded of the major pulse crops and are between lentil and common vetch in number of seeds per pound. In 3 years of trial, they yielded significantly less than navy or adzuki beans and were later and very indeterminate in maturity. Good seed was produced at Rosemount, however, and the crop is satisfactory for the home garden.

In the last 10 years, cowpeas have increased more in world production than any other pulse. But in the United States, cowpeas harvested as dry peas declined in acreage since World War II from ¾ million to a few thousand. Considerably more acreage is grown for green manure and forage uses than for dry peas. For marketing purposes, cowpeas for human food are called southern peas and are further divided into blackeye, crowder, cream, and "field pea" types. Southern peas are grown in the southeastern and south central United States, and much of the crop is processed by canning or freezing. A large acreage of the blackeye type, grown mostly in California, is the blackeye market class of dry beans. Varieties of cowpeas differ greatly in seed size, but seed of the blackeye type ranges between navy and pink beans in size. Cowpea varieties grown at Rosemount were too late maturing for satisfactory seed yield. Some varieties might have potential for green manure in Minnesota, but seed would have to be grown in the southern states.

Most of the world crop of pigeon peas is grown in India. Seed of the variety Norman is grown in Florida and used in North Carolina and other southeastern states as a green manure crop. But, in trials on silt loam at Rosemount and sandy soil at Elk River, Norman produced less green manure than did soybeans. Varieties differ greatly in seed weight, but Norman has about 6,000 seeds per pound.

Urd bean, horse gram, hyacinth bean, and guar are important pulse crops in India. They bloomed but produced very little seed in plantings at Rosemount. Guar is an unusually drought resistant legume. It is adapted in Texas, Oklahoma, and the southwestern United States for forage, green manure, or seed. The seed is a source of mannogalactan gum, which is used in food and industrial products. The meal remaining after gum extraction is a high protein concentrate for livestock feed. Seed is small; each pound contains about 14,000 seeds.

Structure and Emergence of the Pulse Plant

The primary axis of the pulse plant is composed of root, stem, and the transitional area (hypocotyl) between root and stem. The stem starts at the first node, where two cotyledons (seed leaves) are attached. A node is the cross section of stem where a leaf is attached; an internode is the length of stem between two nodes.

The fruit of a pulse plant is a pod. Each seed is attached to the inside of the pod by a stalk (funiculus) that disappears as the seed matures but leaves a mark (hilum) on the seed. The mature seed consists of a thin seedcoat(s) surrounding a young plant that already has large cotyledons and a very small stem and root.

All pulses have two cotyledons at the first node and are classed epigeal if the cotyledons appear above and hypogeal if they remain below ground (figures 17 and 18). Pulses of the epigeal group emerge by elongation of the hypocotyl, whereas those of the hypogeal group emerge by elongation of the first and sometimes second and third internodes, depending on depth of planting (figure 19). Pulses are classed as follows:

EPIGEAL EMERGENCE	HYPOGEAL EMERGENCE
field bean	field pea
tepary bean	chickpea
mung bean	adzuki bean
blackeye bean	runner bean
cowpea	pigeon pea
guar	broadbean
blue lupine	horsebean
yellow lupine	tickbean
white lupine	common vetch
	lentil
	grass pea

Seedlings with hypogeal emergence are less likely to be killed by freezing, wind erosion, or insect or other animal feeding because new stems can develop from axillary buds at the below ground nodes. In contrast, if the hypocotyl of epigeal pulses is severed, the plant will die because there are no buds below the first node.

Figure 14 (below). Long pods and viny growth of cowpea. Catjang and the asparagus or yard-long bean have recently been classified as cowpeas. Figure 15 (right, top). A large field of pinto beans showing good weed control obtained by herbicides and cultivation with no handweeding. Figure 16 (right, bottom). Pigeon pea is a tall, erect bush, in contrast to the prostrate vine of field pea.

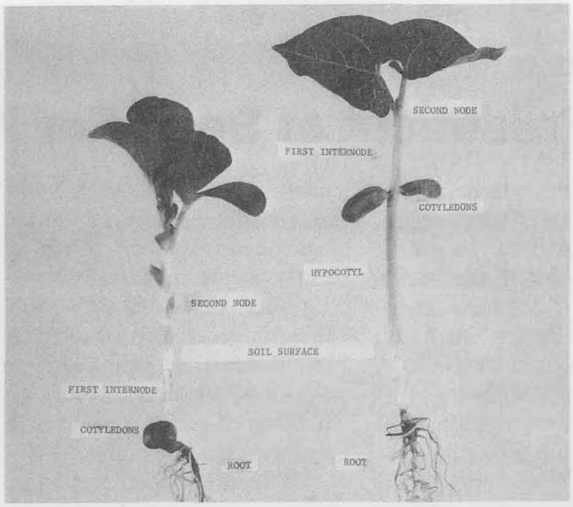


Figure 17. Horsebean cotyledons remain below ground (hypogeal emergence), whereas field bean cotyledons emerge (epigeal emergence).

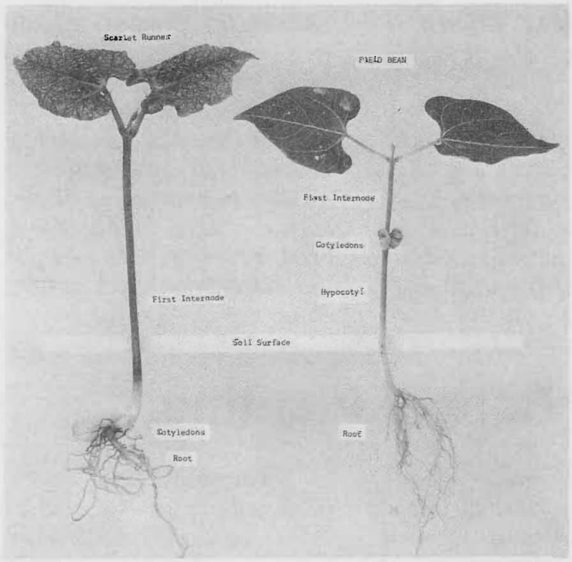


Figure 18. Scarlet runner bean with emergence by first internode elongation (hypogeal), and field bean with emergence by hypocotyl elongation (epigeal).

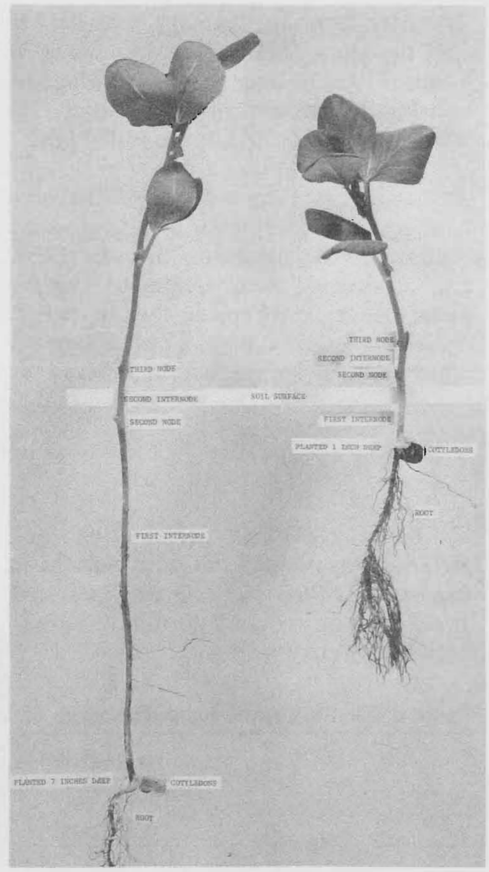


Figure 19. Horsebean (left) was planted 7 inches deep. Its first internode grew 6 inches long, so emergence was completed by second internode elongation (hypogeal).

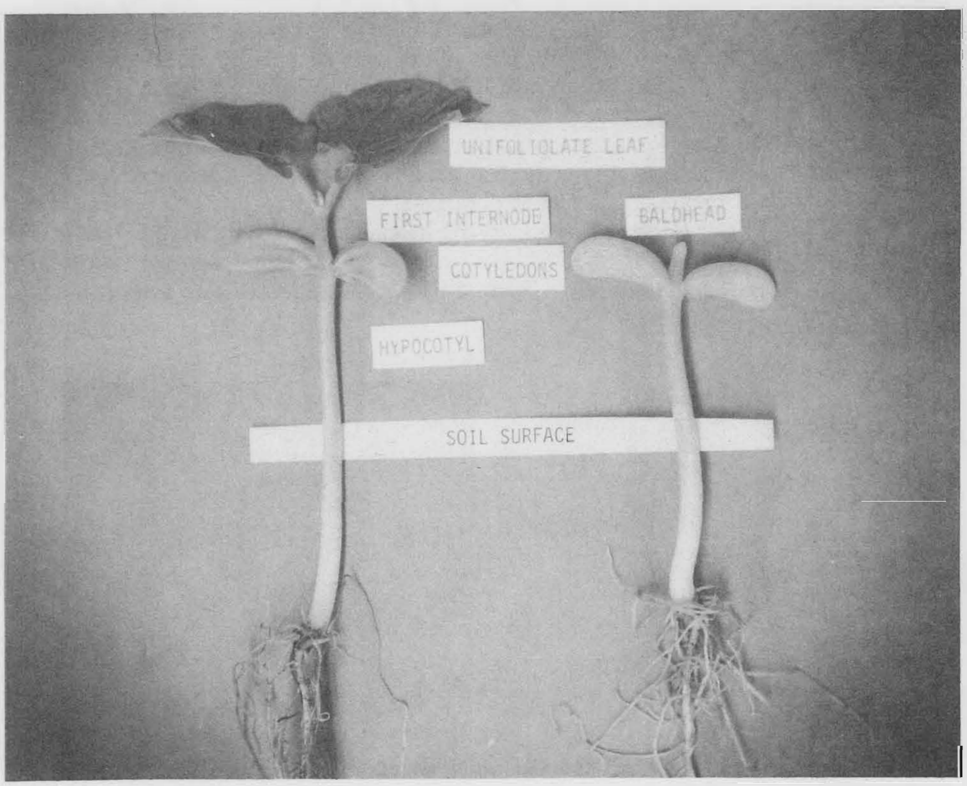


Figure 20. The baldhead plant resulted from internal injury during threshing and handling of the dry seed.

Quality and Treatment of Seed For Planting

Split and crack damage to seeds from threshing, cleaning, and bagging is easily detected. But internal damage also occurs and is more common in pulse than in grain crops. Field bean seed is especially susceptible to mechanical damage compared with other pulses of field crop potential in Minnesota. Some internal damage, such as baldhead (figure 20), of epigeal pulses may not be evident until after emergence and thus may be overlooked in some germination tests. About 50 percent of baldheaded plants will die, and the remainder will develop one or two branches from the axillary bud between each cotyledon and the stem. These branches will produce mature seed about 3 weeks later than undamaged plants. Broken or missing cotyledons or unifoliolate leaves also indicate internal mechanical damage to the seed.

Microorganisms that cause disease of pulse crops are another nonvisible factor affecting seed quality. Fungi and bacteria on the surface of the seed are killed by fungicide and bactericide seed treatment chemicals. Those living under the seedcoat and in the cotyledons are not killed by chemical seed treatment. These internal organisms are kept under control by inspection of seed fields and their rejection for seed stock production if symptoms of seed-borne diseases are evident. The major seed-borne disease has been bacterial blight of field beans. Seed grown in those western states where little rain occurs during the summer is more likely to be free of harmful bacteria. Nonetheless, good seed of all adapted pulse crops can be grown in Minnesota, but field and seed inspections must be rigorous. Growers must expect to divert fields from production of seed for planting to seed for food or feed in years unfavorable for high quality seed production.

Chemical seed treatment of good pulse seed is often unnecessary, but it is used as a relatively low cost disease and insect preventive. Mechanical damage caused by treating the seed and possible detrimental effect on nitrifying bacteria are disadvantages. Most field bean seed planted in Minnesota has been treated with a fungicide to control diseases caused by fungi, with an insecticide to control seed corn maggot and wireworm, and, less commonly, with a bactericide to control bacteria on the seed surface. Some field pea seed is treated with a fungicide. Seed treatment with a fungicide usually increases percentage emergence and vigor of low and average quality pulse seed.

Rate of Planting

Seed weight and germination are the major factors determining pounds per acre needed for a desired population. Suggested planting rates are usually based on seed of 90 percent or higher germination, so rates for seedlots of lower germination should be increased (table 3).

Table 3. Planting rates for pulse crops of field crop potential

Crop	Planting rate/acre: Number of seeds	Planting rate/acre: Pounds of seeds	Seeds/pound, number
PLANTED EARLY WITH A GRAIN DRILL; ROWS NOT CULTIVATED			
Field pea	400,000	190[1]	2,100[1]
Horsebean	200,000	175	1,150
Tickbean	300,000	125	2,400
Lupine	300,000	200[2]	1,500[2]
Lentil	500,000	80	6,500
Common vetch	600,000	70	8,500
PLANTED LATE WITH A ROW-CROP PLANTER; ROWS CULTIVATED			
Field bean[3]	100,000		
Navy	105,000	40	2,600
Pinto	90,000	72	1,250
Pink	90,000	60	1,500
Kidney	81,000	90	900
Adzuki bean	100,000	40	2,500

[1] Century variety. Trapper and Chancellor would be 450,000 seeds/acre, 120 pounds/acre, and 3,800 seeds/pound.
[2] Gela variety. Some white varieties have smaller seed (2,600 seeds/pound). Blue and yellow varieties tested have 2,800 and 3,800 seeds/pound, respectively.
[3] Average numbers of seeds/pound for other market classes of field beans are: small white—2,900; small red—1,350; great northern—1,350; yelloweye—1,050; black turtle—2,550; cranberry—1,000; marrow—900; and brown (not a class)—1,200.

Pulses have large seed, so seed for planting is a major production cost. The yield per pound of seed planted is very low for the early sown pulse crops. The seed yield per acre at Rosemount divided by the seed sown per acre in table 2 indicates that the ratios for pulses exceed 10 to 1, compared with over 30 to 1 for oats. High yielding corn has a 400 to 1 ratio. Thinner stands of early sown pulses may be practical if good herbicides are available. Refinement of planting rate recommendations in various soils to increase the ratio of seed yield per seed planted is a promising research objective.

Herbicides and cultivation are commonly used on field beans. Ratios of seed yield per seed planted commonly range between 10 and 55 to 1, with seed size an important factor.

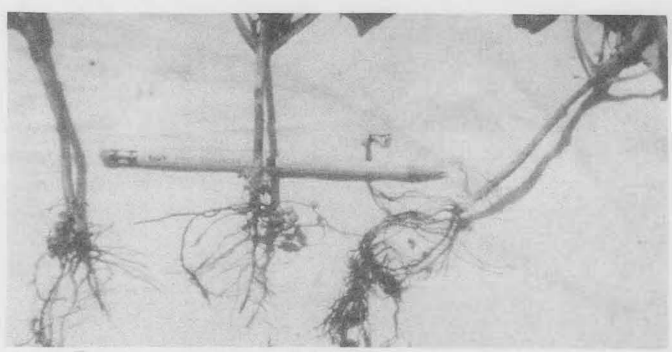


Figure 21. Nodules are present on the roots of pinto bean plants grown from inoculated seed (left and center), but none are present on the plant grown from uninoculated seed (right). More nodulation has generally occurred on pinto than on navy beans in trials at Rosemount and Elk River.

Inoculation and Nitrogen

A major advantage of pulse over grain crops is their lack of need for nitrogen fertilizer. Aerobic bacteria of the genus *Rhizobium* enter the root hairs of pulse plants. The plant increases cell division at the points of entry, thereby producing nodules in which the bacteria convert unusable nitrogen from the air into forms usable by the pulse. Consequently, nitrogen fertilizer is not needed by nodulated pulse crops.

Nodulation depends on the action of the proper kind of rhizobia. Because the kinds needed may not be naturally present in the soil, cultures (inoculants) of living bacteria are mixed with the seed just before planting. Inoculants are fairly specific, and a different strain is often sold for each of the six following groups:

1) field pea, fababean,* lentil, vetch, grass pea
2) field bean, runner bean
3) adzuki bean, hyacinth bean, mung bean, tepary bean, cowpea, guar, pigeon pea
4) lupine
5) chickpea
6) lima bean.

*Inoculants may contain mixtures of bacteria to include more crops. One company sells a distinct strain of rhizobia for fababeans.

Even with the proper rhizobia present, the seedling plant must depend on nitrogen reserves in the seed and in the soil until root nodules are formed. Thus, pulses sometimes appear yellowish after emergence, especially in soil that is low in available nitrogen. Fertilizer nitrogen is sometimes applied to prevent this, but such application may be counterproductive by delaying rhizobial conversion of atmospheric to usable nitrogen.

In contrast to some other pulses, field beans responded to nitrogen fertilizer with increased yields on nitrogen-deficient sand, silt loam, and clay soils in various parts of Minnesota. Nitrogen deficiency is most likely to occur when pulses are grown on irrigated, nitrogen-deficient sandy soil because the available nitrogen is used by the plant or leached out of the surface soil by the irrigation water.

Comparative response of field peas and beans to nitrogen on sandy soil is reported in table 4. Nitrogen significantly increased yield of beans but not peas. The higher pea yield with nitrogen under irrigation was not statistically significant over no nitrogen. Nitrogen tended to increase the protein percentage of bean seed but not that of pea seed. Irrigation significantly increased the protein percentage of pea seed and decreased that of bean seed. Since nitrogen was not a major limiting factor to pea yield, the rhizobia were doing an adequate job of nitrogen fixation. Wild vetches are common in Minnesota, so some soils may have natural populations of vetch (and pea) rhizobia. Field bean rhizobia are probably not present in many Minnesota soils, so the crop responds to nitrogen fertilizer.

Table 4. Effect of seed inoculation with rhizobia and nitrogen fertilizer on yield and protein percentage of dry pea and bean seed at Elk River, 1972-74

	Field peas		Field beans	
Treatment	Dryland	Irrigated	Dryland	Irrigated
	seed yield/acre, pounds			
None	1,517	2,149	1,217	2,341
Rhizobia	1,482	2,234	1,279	2,449
Nitrogen	1,351	2,363	1,625[1]	2,976[1]
	seed protein, percent			
None	23.3	25.2	22.5	19.2
Rhizobia	23.1	24.9	23.6	20.5
Nitrogen	22.4	25.0	25.0[2]	20.0

[1] Nitrogen treatment significantly greater than none.
[2] Nitrogen treatment slightly greater than none but statistically significant in only 1 year.

Inoculation of field bean seed has not significantly increased yields. This may be partly due to the fungicidal seed treatments used. There is little value in inoculating seed that has been treated with a bactericide. Inoculation of pulse crops is a way of introducing the rhizobia into soils lacking these useful organisms. No seed damage occurred in using the wet inoculation method with any of the pulse crops of potential field crop use except for field beans. The wetting and handling of the treated field bean seed was harmful in some instances, so dry inoculation may be safer, but it is less effective. A new alternative to wet seed inoculation is placement of granular inoculant in the bean row through a planter attachment.

Irrigation

Pulse crops respond to irrigation with much higher yields (tables 2 and 5). Benefits from irrigation vary from year to year, depending on rainfall. Because July is the month of highest temperature combined with low rainfall, late pulses such as field beans show especially large yield increases from irrigation. In 5 of 6 years, irrigation greatly increased bean yield (table 5). A yield increase did not occur in 1972 because drought did not occur. The 4½ inches of water applied between June 17 and August 16 was an unneeded addition to 13 inches of rain. In 3 of 4 years (table 5), nitrogen without irrigation was of no value on sandy soil, but nitrogen with irrigation increased yields. Irrigation without nitrogen did not significantly increase yield on low nitrogen soils in 1969-70, whereas irrigation

Table 5. Effect of irrigation on field bean seed yield and protein percentage on sandy soil at Elk River

Year	Treatment and rate/acre, pounds	Seed yield/acre, pounds		Seed protein, percent	
		Dryland	Irrigated	Dryland	Irrigated
1969-70	None	503	680	—	—
	Nitrogen, 99	483	2,576[1]	—	—
1971	Nitrogen, 33	1,019	2,252[1]	26.1	16.4[1]
1972	None	2,451	2,272	19.7	21.2[1]
	Nitrogen, 66	3,090	2,996	20.1	21.0
1973	Nitrogen, 99	619	2,665[1]	25.1	18.4[1]
1974	None	637	2,357[1]	24.0	20.3[1]
	Nitrogen, 99	680	2,717[1]	27.1	20.4[1]

[1] Irrigated significantly different from dryland.

alone increased yield in 1974 because water, not nitrogen, was the limiting factor.

Seeds harvested from irrigated and dryland plots did not differ in appearance. Yet, except for the high rainfall year of 1972 when irrigation was not needed, protein content was significantly reduced by irrigation. Some nutritionists use a value of 22 for the protein percentage of beans. Considerable variation occurs but low protein is undesirable. This research indicates that beans of low protein may be produced on irrigated sandy soils when bean foliage yellows. Peas and other pulses with good nodulation showed less variation in protein percentage than field beans and had higher protein with irrigation than without (tables 2 and 4).

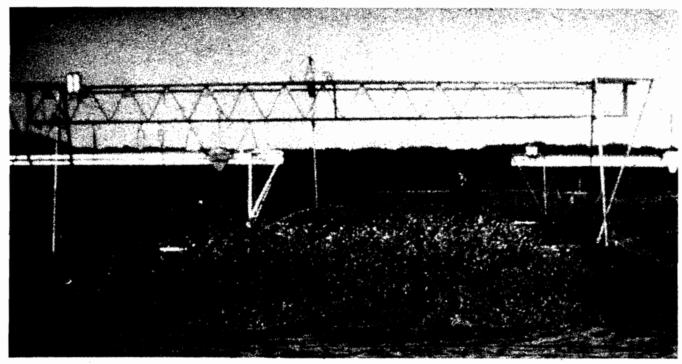


Figure 22. Portable plot irrigators developed by agricultural engineers sprinkle 20- x 50-foot pulse plots.

Crop Sequence and Rotation

PULSE RESIDUES AND NITROGEN

Pulses generally leave the soil in good condition for the following crop. Crop residues are easily incorporated, and only minimum tillage is required in preparation for the next crop. Pulses differ in amount of nitrogen fixation. Fababeans are reported to obtain up to 80 percent of their nitrogen from the air in contrast to peas, which obtain about 30 percent. Because only the seed is harvested and plant residues remain in the soil, pulses rarely deplete soil nitrogen. Consequently, crops following pulses require less nitrogen fertilizer than those following grain crops.

PULSES AS COMPANION AND FORAGE CROPS

Perennial legume and grass forage crops may be established with pulse companion crops. The purpose of the companion crop is to control weeds and produce a crop during the year in which the forage crop is established. Oat, flax, horsebean, and field pea companion crops for establishment of alfalfa, red clover, crownvetch, bromegrass, and timothy were compared on silt loam soil at Rosemount. No herbicides were used, and annual weeds were sufficiently numerous that the forage growth and yield data show the combined effect of companion crop and weed populations (table 6). Oats gave the most weed

Table 6. Effect of companion crop on weed control and forage growth in September at Rosemount

Companion crop	Years sown[1]	Weed control, percent	Forage growth rank in September[2]				
			Alfalfa	Red clover	Crown-vetch	Brome-grass	Timothy
Oat	1962-66	89	3.0	3.2	3.6	4.1	4.4
Flax	1965-66	64	2.3	2.4	4.0	3.1	3.7
Horsebean	1962-65	38	3.2	3.3	4.7	2.1	2.5
Field pea	1962	48	4.8	4.5	—	4.8	4.8
LSD 5 percent		13	0.8	1.0	0.9	0.8	0.8

[1] Data for crops not grown in all years were adjusted to be comparable with oat data.
[2] 1 most, 5 least.

Figure 23. Effective weed control is evident in the center strip of navy beans, which was sprayed with herbicides.

Figure 24. Navy beans at the left are nearly ready to harvest; those at the right are less mature.

control and horsebeans the least. The forage growth rank in September indicates that the best companion crop for legumes was flax and the best for grasses was horsebeans. The high vigor of grasses established under horsebeans was probably caused by more available nitrogen in the horsebean plots. Although field peas were not strong competitors with the forage crops during early growth, they lodged before bloom, and the forage seedlings died under the prostrate vines. These results indicate that long vine pulse crops are hazardous for forage crop establishment.[5] Under less weedy conditions or when the same herbicide can be used for both pulse and forage crop, bush or short vine pulses are potentially excellent companion crops.

Pulse crops can also be used as forage crops; they will give better weed control and better forage companion crop establishment than when allowed to mature as pulses. In comparison with oats for forage, horsebeans yielded less dry matter but were much higher in protein percentage and protein yield per acre (table 7). At optimum forage stage, pulses will be at least 10 percentage points higher in moisture than small grain and consequently will take longer to cure.

Oats and a pulse crop grown in mixture for forage usually give higher yield and better weed control than the pulse grown alone. Moisture percentage of the mixture at optimum forage stage is usually 2 to 5 percentage points higher than oats alone but 5 or more percentage points lower than the pulse alone. Protein percentage of the mixture is between those of the pulse and oats grown alone. Oats plus field peas, the most common mixture, are well adapted to eastern and northern Minnesota. Forage yields of oats alone and oat-pulse mixtures did not differ significantly either on silt loam soil at Rosemount or on clay soil at Duluth. However, the mixtures produced more protein per acre than did oats alone (table 8). The oat-

Table 7. Comparison of Lodi oats and horsebeans as forage crops at Rosemount, 1970-74

	Forage		
Crop	Protein, percent	Yield/acre, pounds[1]	Protein/acre, pounds[1]
Oat	8.7	7,346	640
Horsebean	15.0	6,239	934
LSD 5 percent		703	

[1] 15 percent moisture basis.

Table 8. Comparison of oats alone and oat-pulse mixtures as forage crops on silt loam soil at Rosemount, clay soil at Duluth, silt loam soil in southwestern Minnesota, and sandy soil in Anoka County

	Forage		
Crop and planting rate/acre, pounds	Protein, percent	Yield/acre, pounds[1]	Protein/acre, pounds[1]
ROSEMOUNT, 1954-57, 1962-65			
Oat, 80	7.5	6,581	509
Oat, 64 + horsebean, 60[3]	10.2[2]	6,771[2]	692[2]
Oat, 48 + field pea, 90[4]	10.5	6,419	674
Oat, 64 + vetch, 20-40[5]	8.9	6,571	594
LSD 5 percent	1.2	390	162
DULUTH, 1959-63			
Oat, 80	7.9	3,713	293
Oat, 64 + horsebean, 60[3]	10.7[6]	3,835[6]	410[6]
Oat, 48 + field pea, 90[4]	9.7	4,044	392
Oat, 64 + vetch, 30-43[5]	7.8[6]	3,770[6]	294[6]
LSD 5 percent		556	
SOUTHWESTERN MINNESOTA,[7] 1954-57			
Oat, 80	8.1	5,513	432
Oat, 48 + field pea, 90[4]	11.1	5,084	549
Oat, 64 + vetch, 20[5]	8.9	5,342	466
LSD 5 percent	1.4	357	95
ANOKA COUNTY, 1954-57			
Oat, 80	7.9	2,903	214
Oat, 48 + field pea, 90[4]	10.4	3,869	428
Oat, 64 + vetch, 20[5]	11.4	3,519	394
LSD 5 percent	3.5	387	166

[1] 15 percent moisture basis. [2] 1962-65 data adjusted to be comparable with the 8-year average data. [3] 68,000 horsebean seeds per acre. [4] 300,000 pea seeds per acre. Lower cost and more commonly used rates are 150,000 to 200,000 peas plus 64 pounds of oats per acre. These lower rates of peas result in less lodging but lower protein forage. The lower rates are best on fields where peas are well adapted, particularly in eastern and northern Minnesota. [5] 300,000 vetch seeds per acre. [6] 1962-63 data adjusted to be comparable with the 4-year average data. [7] Redwood, Murray, Brown, and Nobles Counties.

[5]This may not be true with canning peas because the lodged vines are removed early. Canning peas, however, are harvested when ready, even when the soil is wet, so harvesting machinery may destroy the stand or roughen the field too severely for later harvesting of forage.

horsebean mixture was as productive as oats-peas and has potential for some soils where oat-pea mixtures lodge severely. Horsebeans are not adapted to sandy soil. Neither field peas nor horsebeans are consistently productive in southwestern Minnesota, and oat-pea mixtures yielded less forage but more protein than did oats alone (table 8). On the nitrogen-deficient sandy soil in Anoka County, oat-pulse mixtures yielded more forage and protein per acre than did oats alone.

Oat-pulse mixtures used as companion crops may provide more competition to seedling legume, grass, or rape forage crops than either crop grown alone. Nonetheless, satisfactory stands have developed where moisture was favorable and severe lodging did not occur.

ROTATION AND DISEASE CONTROL

Crop rotation is a major method of disease control. Small grains and corn are the best crops to separate pulse crops in a rotation because these grain crops do not support the most important disease-causing pathogens of pulses. Most common nongrass crops and many weeds are affected by the same diseases as pulses.

Pathogens vary in their longevity in the soil, but from 1 to 6 years is a practical range for those controlled by crop rotation. A minimum time between pulse crops should allow all stem and root residues to decompose. On well drained soil, this takes 1 or 2 years. Although this minimum time is enough to help control rust and other organisms that require pulse residues for survival, longer rotations usually are recommended. Crop rotations of practical length can only be expected to reduce the amount of inoculum carryover, not eliminate it. A reasonable objective is at least 3 or 4 years between pulse crops, including at least 1 or 2 years of grain crops immediately preceding the pulse. If a disease becomes serious on a field, a longer time must elapse between pulses or other susceptible crops. Certain nongrass crops and some pulses are particularly damaged by the same strain of pathogen, so these crops should also be 3 or 4 years apart in the rotation. Field beans and sunflower are one example.

Weed Control

Weeds greatly increase production costs and are a major deterrent to pulse crop production where hand labor is not financially practical. Cultivation for crops grown in wide rows and harrowing for those planted in narrow rows are the major mechanical methods of weed control.

If crop emergence is slow, emerging weeds are killed by preemergence spiketooth or coil spring harrowing. After crop emergence, the coil spring harrow, spiketooth harrow, rotary hoe, or weeder is used to kill weeds selectively. The basis of selectivity is differential size; the crop must be firmly rooted, and then small emerging weeds in the white stage can be destroyed without injury to the crop. The best weed kill, least crop damage, and least spread of disease organisms occur on a clear day when foliage and soil surface are dry. Speed of the tractor, setting of the harrow, and weighting of the rotary hoe are the varied adjustments used to kill the most weeds with the least injury to the crop.

Effective herbicides have been found for most of the pulses, but many have not been approved by the EPA. Crops on which herbicides can be used usually are listed on the herbicide container. Recommendation of effective herbicides was the major technological change leading to the large increase in Minnesota's field bean acreage during the 1970's.

Pulse crops generally show similar tolerances and susceptibilities to herbicides, but there are important differences. Some of the presently approved and effective herbicides for certain weeds in field beans, field peas, and lentil are listed below along with rates of application. Herbicides have not been approved for fababean or lupine in the United States.

	Crop and herbicide rate/acre, pounds		
Herbicide	Field bean	Field pea	Lentil
PREPLANT INCORPORATION BY DISK OR OTHER TILLAGE			
Trifluralin (Treflan)	½-1	½-¾	½*
Profluralin (Tolban)	½-1	—	—
EPTC (Eptam)	3	—	—
Dinitramine (Cobex)	⅓-⅔	—	—
Propham (IPC)	—	4	4
Diallate (Avadex)	—	1¼	1½
Triallate (Avadex BW, Fargo)	—	1¼	—
PREEMERGENCE			
Chloramben (Amiben)	2-3	—	—
Dinoseb amine (Premerge)	7½-9	6-9	—
Chlorpropham (Chloro IPC)	3	—	—
Diallate (Avadex)	—	1¼	1½
Triallate (Avadex BW, Fargo)	—	1¼	—
CROOK OR EMERGENCE STAGE			
Dinoseb amine (Premerge)	3-4½	—	—
POSTEMERGENCE			
Dalapon (Dowpon)	—	¾	—
Dinoseb amine (Premerge)	—	¾-2¼	—
Dinoseb ammonium (Dow Selective)	—	¾	—
MCPB sodium salt	—	½-1½	—
MCPA	—	⅛-⅜	—
Barban (Carbyne)	—	¼-⅜	¼-⅜

* Approved by EPA, but manufacturer does not recommend use because it may injure lentil. Some growers use it because their weed problem is greater than the chemical injury hazard.

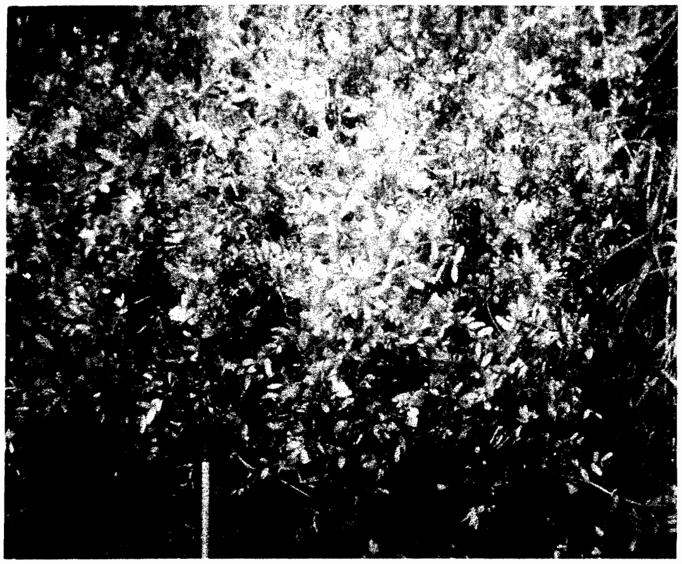


Figure 25. Lentil at the proper stage for windrowing. The lower pods are dry.

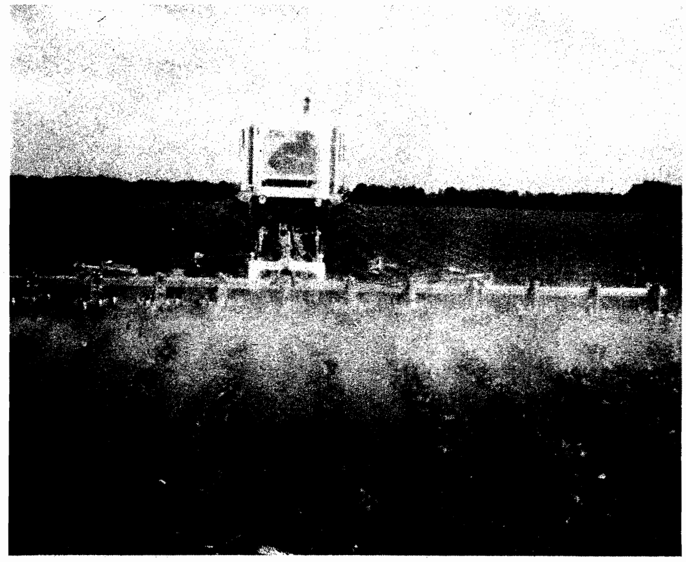


Figure 26. Hilling up pinto beans in preparation for pulling about 2 months later raises a cloud of dust behind the cultivator.

Harvesting

Pulse crops are harvested by combining the standing crop, by cutting the crop with a windrower or mower-windrower combination and combining the dry windrow, or by pulling and windrowing the crop and combining the dry windrow.

Considerations in choosing a harvesting method include growth habit, seed shattering hazard, uniformity of maturity, and weed plant population. Varieties of bush growth habit are more adapted to direct combining and usually suffer less weather damage to their seed than do similar varieties of viny growth habit. Seed shattering losses are reduced by harvesting before all pods are dry and by doing this harvesting at night or in the early morning when pods are still wet with dew. None of the pulse crops ripen and dry as evenly as small grain or soybeans, so direct combining is often impractical. Many pulses bloom over a long period of time, and harvest must sometimes be accomplished when the crop still has green leaves, flowers, ripe pods, and green pods. Weeds growing in a mature pulse crop may necessitate windrowing even though the pulse alone could be combined directly.

Field peas are prostrate vines at maturity. The long pea vines make either windrowing or direct combining difficult because vines outside the width of cut are pulled into the machine. Therefore, attachments resembling a circular power saw or a cutting disk are used to separate swaths. In most situations, the dry vines will break off at soil level if combined directly using a windrow pickup attachment instead of a cutterbar on the combine (figure 28). Green weeds remain rooted in the soil and do not go through the combine. In other situations, the vines do not break off at ground level and the peas must be windrowed using a reel with pickup fingers and pea guards on the cutterbar. Or a mower with pea guards and a windrower attachment may be used.

Common vetch is a prostrate vine, but it usually will not break off at ground level like peas. So the crop is cut and the windrow is combined when dry.

Horsebean, tickbean, and lupine have bush type growth with pods high off the ground; they can be direct combined using the cutterbar attachment or windrowed and combined. Fababeans will shatter if left standing until dry, so they are cut when the leaves have dried, the lower pods are black, and most seed can easily be detached at the hilum. Maximum moisture for storage of fababeans in Canada is 16 percent, but this is probably too high in Minnesota, especially in the spring and summer. Some lupine varieties resist shattering and can be combined when dry. Other varieties shatter easily and are combined when shattering starts and then dried to about 12 percent moisture.

Lentil has a short bush growth habit and often lodges. The crop is cut when the lower pods are dry and the plants are still leafy but yellowish in color (figure 25). Drying in the windrow takes about 1 week when drying conditions are good. Seed should not exceed 13½ percent moisture for safe storage.

Field bean varieties of both bush and vine type often are not available in the same market classes. With both types, the standard procedure is to prepare for harvest by hilling up the rows at the last cultivation (figure 26). At harvest, a blade resembling a long plowshare is pulled below each row about 1½ inches deep. Some of the bean plants are cut and the rest are pulled to the surface and guided into windrows by steel rods on the puller (figures 29 and 30). Then the small windrows of two rows each are raked into larger windrows. Drying in the windrow takes from 1 to 10 days, depending on type of bean and stage when cut. The ideal moisture percentage when delivered to the processing plant is 15 percent for pinto and pink varieties and 17-18 percent for navy and kidney. For long

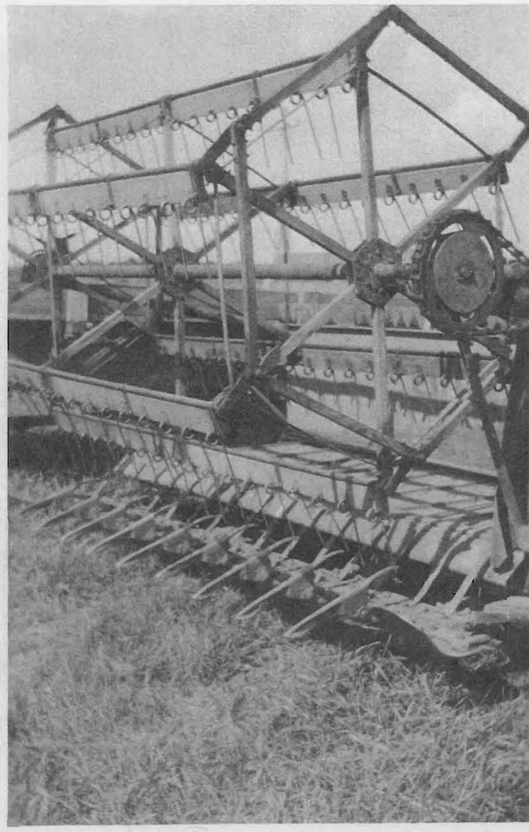
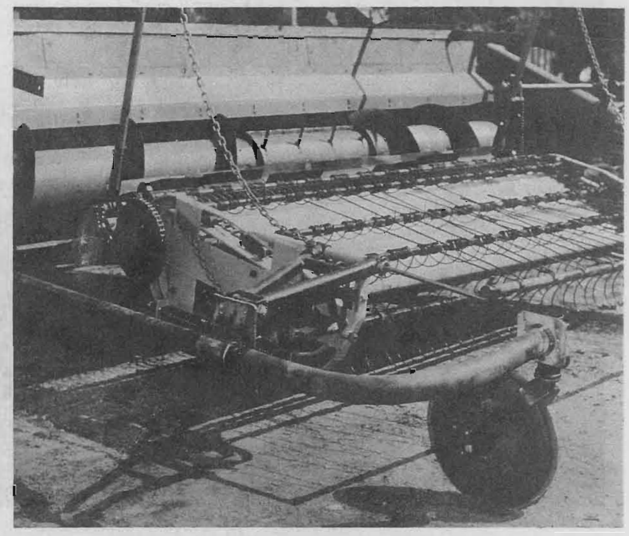


Figure 27. Windrower with pickup fingers on the reel and pea guards for cutting vine-type pulse crops. The guards in front of the cutterbar sickle slip under and raise the vines so that the sickle cuts the stems below the pods.

Figure 28. The raking type pickup breaks dry field pea vines at soil level and pulls them into the combine auger. The disk (shown in the foreground) separates swaths. An attachment resembling a circular saw also is available for separating swaths.



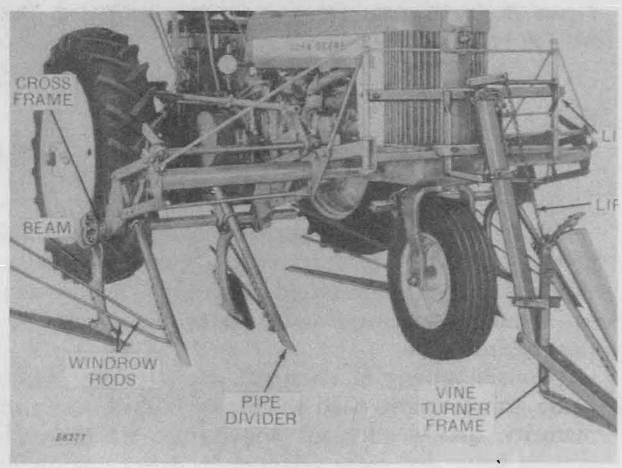


Figure 29. Blades on this four-row bean puller throw two rows between the rear tractor wheels and one to the outside of each wheel. This arrangement is used for wide row widths. In 20- to 28-inch rows, all four rows might be thrown between the rear tractor wheels.

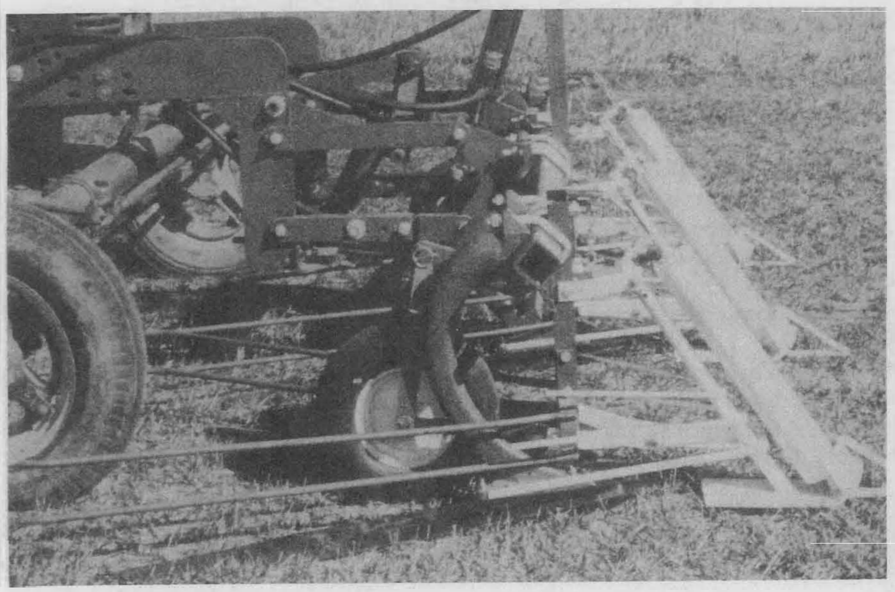


Figure 30. A front mounted bean puller showing a blade in the foreground with two windrowing rods above it.

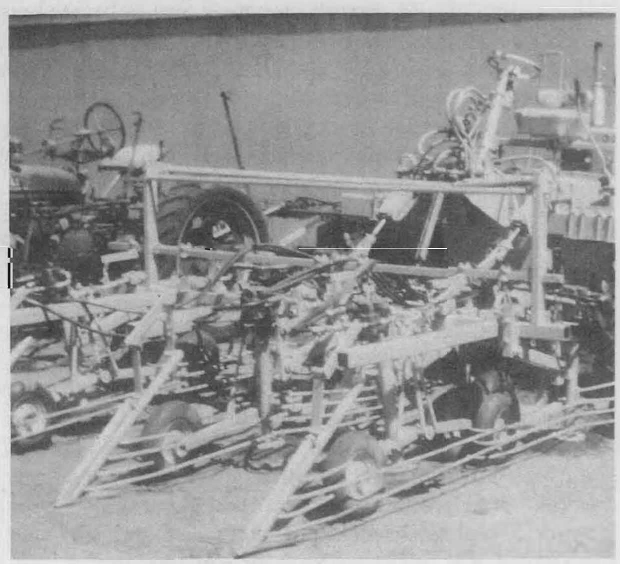


Figure 31. A front mounted bean puller with notched disks instead of blade pullers.

time storage, however, bean moisture should be 12 to 15 percent, and beans in storage should be checked occasionally for signs of deteriorating quality. Beans above 14 percent in moisture are especially likely to deteriorate. Beans below 12 percent moisture are brittle and undesirable for processing.

Bush varieties of field and adzuki beans can be harvested without using a puller, but considerable seed may be lost even when the field is left as level as possible at the last cultivation. Comparative losses from windrowing and combining a bush navy and a viny pinto variety in a trial at Rosemount amounted to no loss of seed when windrowing navy but severe loss of seed when windrowing pinto. Combining losses were about the same for both varieties. The yield of combined seed was 1,847 pounds per acre for navy and 1,095 pounds per acre for pinto. Losses from windrowing plus combining amounted to 10 percent for navy and 59 percent for pinto. These data show that large losses can occur in harvesting a prostrate vine variety if the pulling operation is omitted.

The large size and heavy weight (usually over the legal weight of 60 pounds per bushel) of pulse seed facilitates easy separation of seed from trash, but splitting of seed and cracking of seedcoats is sometimes serious. Combine cylinder speed with pulse crops is slow, often 200 to 400 revolutions per minute. Clearance between concave and cylinder bars is carefully adjusted to allow seed to pass through without breakage. Pulses with very easily broken seed, such as kidney field beans, usually are harvested with combines specially constructed to prevent seed breakage. Use of augers in moving dry seed from storage is avoided by using belt conveyors where possible.

Beans differ greatly in susceptibility to mechanical damage. Kidneys are the most susceptible. Great northern, adzuki, navy, marrow, yelloweye, cranberry, small red, and brown are very susceptible. Small white is tougher than navy. Pinto and pink are more resistant, but even these are more easily damaged than soybeans. The early sown pulse crops are much less susceptible to splitting than the late sown beans, but all require greater care in harvesting and handling than do small grains. Lentils are the most easily damaged of the early sown group, in contrast to horsebeans and tickbeans, which are moderately resistant to seed damage.