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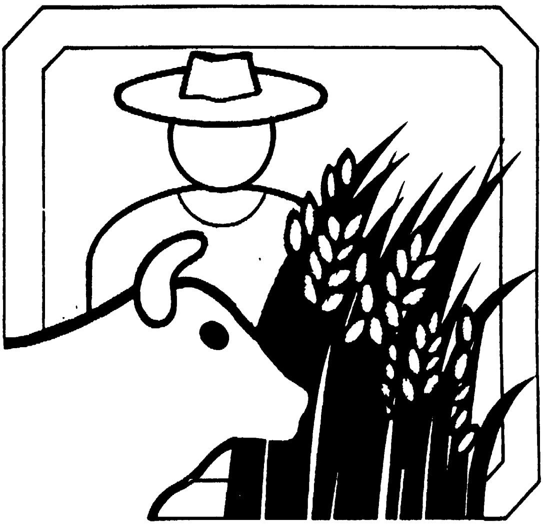

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VARIETAL IMPROVEMENT OF PIGEONPEA FOR SMALLHOLDER LIVESTOCK PRODUCTION SYSTEMS

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INTRODUCTION

Pigeonpea (*Cajanus cajan*) is widely grown in the tropics and subtropics as a source of seed for human nutrition. It is most commonly used as *dhal* (dry split seed) in vegetarian-based diets on the Indian subcontinent. The seed contains 20-25% protein. However, as we show in this paper pigeonpea seed also has considerable potential for animal feed and the plant as forage.

Pigeonpea plants and grain probably have been used as animal feed for centuries by the Indian farmer. Even today plants are left in the field after all other crops are harvested to be grazed by animals. Watt (1908) reported that in India dry pigeonpea leaves were valued as fodder and the threshing from pods was used as food for milking cows. Pigeonpea was an important forage crop in Hawaii for many years (Krauss, 1932). There it was used as a hay crop with the top 1/3 of the crop cut when a large percent of the pods were mature. When grazing the animals likewise ate about the top 1/3 of the crop consuming branches up to pencil thickness. Pigeonpea was found to be an excellent replacement for imported feedstuffs. In large scale trials production of 1,000 kg beef/ha has been obtained, outproducing grass pasture by about 100 kg/ha in a 200 day trial (Krauss, 1932). The grain was found good for feeding milking cows as a protein source to substitute for soybean.

These and other early studies of the use of pigeonpea as forage, fodder, and feed for animals have been reviewed by Akinola et al. (1975a, b) and Whiteman and Norton (1981).

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Pigeonpea is a short-lived perennial with a number of advantages over other leguminous crops. These include drought tolerance, lodging and shattering resistance, and perenniality, which allows the possibility of ratoon crops. The perenniality of the crop also enables consideration of various production systems that would incorporate its use as an animal feed, for example using crop residues, and ratoon crop growth.

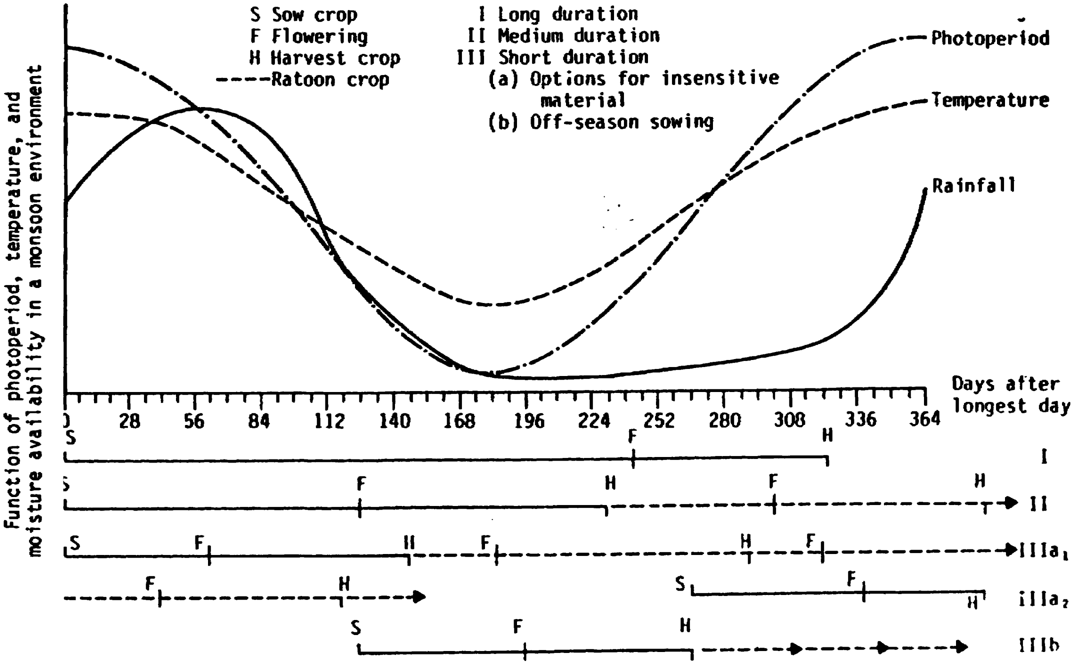
Several disadvantages are recognized for the crop including susceptibility of the plant to waterlogging and frost damage, and of the pod and seed to insect attack. In addition, most cultivars now grown are of long duration, which restricts their adaptation. Crop losses due to several diseases can be serious in much of Asia.

The great diversity of habit and use of pigeonpea makes its improvement for the smallholder livestock producer a most complex and interesting challenge (Byth et al., 1981). As for most tropical and subtropical legumes, little formal plant improvement has been attempted in pigeonpea compared with the major cereal crops. This implies that relatively large genetic improvements in production can be attained rapidly. However, transfer of particular improvements between genetic materials adapted to the diverse production systems in this crop is a major problem.

APPLICATIONS IN AGRICULTURAL SYSTEMS

Production Systems of Pigeonpea for Seed

Pigeonpea is produced in a diverse array of systems. This is in part due to the wide range available in phenological development extending from photoperiod-sensitive long duration (9-11 months) or medium duration (6-8 months) types to photoperiod-insensitive short duration (3 1/2 month) genotypes. Phenological development is influenced by photoperiod and temperature, and response to these factors governs the ecophysiological adaptation of pigeonpea. Byth et al. (1981) have defined generalized production systems for pigeonpea seed production (Figure 1). In this classification it is clear that many production systems are possible including those that exploit the perennial nature of the crop for seed and/or in ratoon crops.



1. Generalized classification of production systems in pigeonpea (After Byth et al.,1981).

Traditional Intercrop Farming Systems

In India and eastern and southern Africa most pigeonpea is grown in intercrop situations, in which long duration pigeonpea is grown in rows that are wide apart (1-1.5 m or greater) with another crop such as sorghum, millet or maize in the interrow space. The cereal is harvested prior to flowering of the pigeonpea which then completes its crop cycle on residual moisture during the dry season.

A great diversity of intercropping systems is practiced including some in which the pigeonpea component is very low. However, Willey et al. (1981) have described intercropping systems of pigeonpea and other crops in which the intercrop yield of the other crop is not significantly reduced compared to a sole crop of that species and up to 70% of a sole pigeonpea crop can also be obtained.

Sole Crop Systems

In general, sole crop systems are most relevant to medium-duration and short-duration genotypes although very high seed yields have been reported from sole-crop long-duration pigeonpea in north India. As with all sole-crop agriculture, there is a requirement to optimize plant population and arrangement if high seed yields are to be obtained.

Change of sowing date or latitude has substantial influence on the phenology and vegetative development of photoperiod-sensitive material. As a result, large sowing date + plant density/arrangement interactions exist, and this makes management an important determinant of seed yield. For example, even short duration photoperiod-sensitive cultivars such as cv Royes can be sown at or after the longest day in order to reduce the pre-flowering period and thus avoid excessive vegetative growth (Wallis et al., 1979). Even then, plant population has to be varied from 50,000 plants/ha for sowing at the longest day to 250,000 plants/ha for sowing 2-3 months after the longest day, in order to obtain optimum canopy development and maximum seed yield.

Although high seed yields are possible using this production system, using photoperiod sensitive pigeonpea genotypes sown after the longest day, it has limited application in many agricultural environments because of its complexity of management and because pod and seed development occurs during the coolest and/or driest period of the year. In warmer environments, such as in Fiji, the production system has been successful. Ratoon cropping is feasible in favorable environments (Wallis et al., 1981) and experimental yields exceeding 4 t/ha/annum from two harvests have been achieved.

Photoperiod insensitive cultivars that flower in approximately 60 days have recently received considerable research interest. These cultivars will flower and mature in approximately the same time regardless of sowing date, provided temperature is not limiting. Ratoon cropping is feasible. For example using the recently released cv ICPL 87 a total yield of 5.5 t/ha was obtained in three harvests after a total of 217 days (ICRISAT, 1984). Little plant improvement has been attempted in this production system so far. Despite this, extremely high seed yields have been obtained experimentally (Wallis et al., 1983), with line mean yields from a plant crop in excess of 8 t/ha under favorable conditions. Plant populations of about 500,000 plants/ha are necessary (Wallis et al., 1981) and such crops produce canopies that are suitable for mechanical harvesting.

Hybrid pigeonpea, pioneered at ICRISAT, shows promise of providing even higher yields than normal cultivars. For example the short duration hybrid ICPH 8 yielded 3.9 t/ha at Hisar in 1981 compared to the high yielding control cv T 21 at 2.9 t/ha (ICRISAT, 1982). In 1984 ICPH 8 averaged about 25% higher yield than the best control cv UPAS 120 in 15 trials throughout India (ICRISAT, 1986).

These short season production systems have been tested internationally since the early 1980's. It is clear that under favorable conditions yields in excess of 2.5 t/ha from the plant crop are possible in a wide range of environments (for example Hisar, in Northern India, Gupta, pers. comm.; Khon Kaen, Thailand, Wimolrat, pers. comm.; Nadi, Fiji, Singh, pers. comm.; and Yezin, Burma, L. Singh, pers. comm.). Further testing of these production systems for dry seed is being carried out, including their potential for ratoon cropping.

This research into short duration pigeonpea has been intensified in India and Australia since the mid 1970's. In India the emphasis has been in developing short duration cultivars that can fit into the wheat rotations of northern India. This requires that the crop be harvested before the middle of November so that wheat yields will not be reduced by late sowing. Cultivars have been developed for this purpose and experimental yields of up to 4.5 t/ha (Gupta, pers. comm.) have been obtained. Farmers in north India are beginning to adopt this practice and the early incorporation of disease and pest resistance remains a high priority (Kanwar, 1981).

In Australia, research has been conducted since 1970 into the development of production systems to exploit the perennial nature of the crop. These production systems have used early maturing, photoperiod insensitive material that is grown at high plant populations around 500,000 plants/ha). The objective of these studies has been to synchronize flowering by using determinate cultivars and high density plantings to enable efficient insect control and allow the possibility of mechanized harvesting. Yields of these early maturing types have been most encouraging (Table 1). Very similar results reported later have been obtained at ICRISAT.

Table 1. Yields of some pigeonpea lines[a] at three locations in southeastern Queensland in 1984.

	Redland Bay		Kingaroy		Gaton	
Entry	Seed size, g/100 seeds	Yield, kg/ha	Seed size, g/100 seeds	Yield, kg/ha	Seed size, g/100 seeds	Yield, kg/ha
QPL 503	10.6	2400	8.2	2500	9.7	3800
QPL 550	11.2	2300	8.6	2300	9.9	3900
QPL 40	10.9	2600	7.5	2500	-	-
QPL 137	10.2	2100	-	-	8.7	4000
QPL 274	-[b]	-	7.8	3000	10.5	3800
Hunt (Check)	9.3	850	6.1	2400	8.7	2700
Trial mean (n=19)		2000		2300		3600
CV, %		23		23		12

[a]Restricted to genotypes of 60-70 days to flower, sown at 400,000 plants per hectare.

[b]Not ranked in top ten entries at a particular site.

In addition to testing in Australia the ACIAR supported project has been able to evaluate this material in Fiji, Indonesia, and Thailand. ICRISAT material has also been evaluated in several other countries in south and southeast Asia.

Yields in all countries have been most encouraging and it is now planned to evaluate utilization of pigeonpea seed for a number of uses including human food and as animal feed.

A further advantage of the perennial nature of this crop is to provide a homeostatic mechanism to stabilize yield where environmental factors such as drought or biotic factors such as insect pests impose stresses at particular phenological stages. Perenniality enables pigeonpea to produce new flushes of flowers following relief of such stresses, and plants can proceed to develop viable albeit deferred seed yields where other crops may fail.

These seed production systems may be integrated with forage systems as discussed below.

Rice-Based Farming Systems

There is considerable interest in a number of legume crops sown after paddy rice to utilize residual soil moisture. Pigeonpea is one legume found worthy of testing in this system. As a dry seed production system the environment in the paddy after rice has particular limitations such as restricted available water, poor physical structure of the soil, and the possibility of waterlogging with unseasonal rainfall. Because they may escape the effect of these factors early maturing cultivars are being tested. These include adapted photoperiod sensitive and insensitive lines (Figure 1). In either case the plant crop and/or ratoon can be utilized as forage or seed plus crop residue, provided adequate water is available. For example, yields of about 24 t/ha of pigeonpea forage and over 3 t/ha of grain have been obtained at the IRRI Farm (Table 2).

Table 2. Performance of ICRISAT pigeonpea lines sown after wetland rice under zero tillage conditions at IRRI Farm, 1984-85 dry season.

Line	Days to flower	Yield, t/ha		
		Grain	Fodder	TDM
ICPL 84060[a]	70	3.25	18.1	7.27
ICP 909-E3-5EB[a]	71	2.77	16.6	5.94
ICP 3009-E3-4EB[a]	70	2.69	23.8	9.35
ICPL 318	78	2.57	13.5	4.02
ICP 2223-1-E8-6E[a]	74	2.54	21.3	8.01
ICPL 295 (C 11 Sel)	75	2.52	16.3	5.93
ICPL 314	61	2.47	6.5	2.14
ICPL 265 (LRG 30 Sel)	84	2.23	21.3	8.78
ICPL 315	65	2.20	6.9	2.59
ICPL 8309	63	2.19	6.3	2.28
ICPL 8311	58	2.16	5.5	1.96
Mean (n=24)	69	2.04	10.4	3.77
C.F. (%)	16	36	22	36

[a]Insect resistant lines.

Production Systems for Forage Pigeonpea

In any of the cases mentioned above, the crop can be utilized for forage. Long duration cultivars have been used solely for producing forage (Krauss, 1932; Schaaffhausen, 1965; Akinola et al., 1975a) and some early material have been evaluated as dual purpose for forage and seed production (Wijnberg, 1983).

Interest in utilization of pigeonpea as a potential source of forage for livestock is related to its high dry matter production. Whiteman and Norton (1981) and Wijnberg (1983) have reviewed the available literature on dry matter production in pigeonpea. It is clear that forage yields are variable and dependent on crop stage, cultivar, and management. Yields of total dry matter of up to 57 t/ha have been recorded (Herrera et al., 1966). However, much of this dry matter is non-edible as up to 50% would be stem material.

Short duration pigeonpea also has demonstrated its potential for high forage production when sown before the longest day (April) at Hisar in India and grown through the very hot months of May and June. Grown this way this crop has given dry stalk yields of up to 32 t/ha and seed yields of 3 to 4 t/ha (Table 3). Although no measurements of actual forage produced by the crop was made it should be substantial considering the large amount of seed and stalk produced.

Table 3. Performance of two early maturity pigeonpea lines sown in April 1983 in separate trials before the longest day at Hisar, India.

Entry	Growth habit	Days to flower	Yield, kg/ha (Nov) Grain	Dry stalk
ICPL 87	Determinate	76	3840	22800
Mean of trial (n=13)	Determinate	75	1970	13240
ICPL 161	Indeterminate	191	2490	32180
Mean of trial (n=14)	Indeterminate	177	2013	19280

USES OF PIGEONPEA

Seed

For human consumption. Pigeonpea improvement programs have been almost exclusively aimed at raising the seed production level of the crop. The major use of pigeonpea seed will undoubtedly remain for human consumption where it has many uses. These include dhal (decorticated split seed), whole dry seed, green seed as a vegetable, and possible new uses such as for making tempeh and ketchup (Wallis et al., 1985).

For animal feed. Although the most remunerative market for good quality pigeonpea seed is likely to be for human consumption, in some situations it is possible to profitably include the seed in compound rations fed to livestock.

For example, in many developing countries, imported protein sources such as soybean meal, and maize to feed poultry and pigs, are a significant drain on foreign exchange. This problem can be exacerbated by the fact that the import price of a crop such as soybean may be below the cost of producing it in the country. To reduce this drain on foreign exchange it may be possible to substitute these imported products with more cheaply grown local crops such as pigeonpea.

The value of pigeonpea as a substitute for soybean may be enhanced when some of the high protein lines developed at ICRISAT from intergeneric crosses become available. Several of these lines, averaged over 3 years, have produced over 30% more protein in their seed than the control cv C 11 (ICRISAT, 1984). One medium maturity line, HPL 40 with good seed size but only about 16% more protein than normal cultivars, produced over 20% more protein per ha than the control cv BDN 1 in tests at ICRISAT (Table 4). Crosses have been made to transfer the high protein character into short duration high performance cultivars.

Relatively little research has been conducted on the feeding of animals with pigeonpea seed (Whiteman and Norton, 1981). We will now examine some recent research on using pigeonpea grain for feeding animals.

The nutritional quality of pigeonpea grain has been well reviewed by Singh and Eggum (1984) and Singh et al. (1984). Their work highlighted the relative deficiency of the sulphur amino acids methionine and cystine in mature grain and the considerable variation that exists in antinutritive factors between varieties.

Table 4. Performance of HPL 40 selections grown at ICRISAT Center, rainy season 1985.

Entry	Days to flower	Seed size g/100 seeds	Grain yield, kg/ha	Protein	
				%	kg/ha
HPL 40-5	115	9.6	2096	26.9	565
HPL 40-17	117	8.5	2074	26.5	550
HPL 40-11	118	9.1	2127	25.7	547
HPL 40-7	117	8.7	2105	25.9	546
BDN 1 (Check)	115	9.6	2022	23.2	466
Mean (n=24)	117.4	9.10	1809.0	26.30	474.8
SE	1.0	0.18	181.0	0.46	46.6
CV, %	1	3	17	3	17

Feeding trials using young growing pigs (Falvey and Visitpanich, 1980a,b; Visitpanich et al., 1985a, b) have demonstrated that pigeonpea meal has to be moist heat-treated in order to prevent depressions in animal growth rate. Apart from the practical difficulties involved in heat treating grain prior to feeding, it is well known that significant losses in essential amino acids, especially lysine and methionine, can occur during such processing.

Recent work at the University of Queensland has investigated the potential of pigeonpea grain to substitute for cereal grain and vegetable protein meals in poultry diets using least cost formulation to meet the nutrient requirements of the bird.

In the first experiment (George and Elliott, 1986) raw and heat-treated pigeonpea were included at varying levels in the diets of week-old chicks. Feed intakes and liveweight gains were measured over a three-week period and compared to the performance of chicks fed a commercial chick grower diet with 12.5 MJ metabolizable energy and 200 g crude protein/kg. Although heat treatment at 120°C for 20 min reduced antitrypsin activity from 11.6 units/mg in the raw meal to 1.2 units/mg growth rates, feed intakes and therefore feed conversion efficiencies were similar in all groups (Table 5). No chick deaths were recorded during the experimental period.

Prior to the experiment the apparent metabolizable energy (AME) content of the pigeonpea meal was evaluated using the practical Diet Replacement Method described by Sibbald and Slinger (1963). Either raw or heat-treated pigeonpea meals were substituted at a rate of 500 g/kg into a commercial ration (AME content of 12.4 MJ/kg DM).

Table 5. Mean feed conversion efficiencies (FCE), intakes and Liveweight gains (LWG) of chicks fed diets containing varying levels (g/kg) heat treated or raw pigeonpea meal.

Parameter	Control	Raw pigeonpea			Heat-treated pigeon pea			SE
Level of pigeonpea inclusion (g/kg)	0	150	300	450	150	300	450	
Feed conversion efficiency	2.3	2.4	2.5	2.4	2.3	2.3	2.4	0.17
Feed intake (g/d)	24	25	25	24	22	24	26	3.5
Liveweight gain (g/d)	10.1	10.1	10.1	10.5	10.0	10.3	10.0	1.8

There was no significant difference in AME value between the heat-treated (11.6 ± 0.11) and raw pigeonpea meal (11.5 ± 0.20 MJ AME/kg DM). Recent work by Nwokolo and Oji (1985) had reported a significant increase of 12.1 to 13.2 MJ AME/kg pigeonpea DM before and after heat treatment. However, these workers only included pigeonpea in the diet at 250 g/kg and did not report levels of antiprotease activity. It is possible that at high levels of dietary inclusion other antinutritional factors, such as polyphenolics that are not significantly affected by heat treatment, may influence the nutritive value of the grain (Singh, 1984).

The results of the chick growth trial suggest that once the nutrients limiting optimum growth are provided in adequate quantities even raw pigeonpea can be irсluded at high levels. Springhall et al. (1974) found that pigeopea at above 300 g/kg of a grower ration restricted growth but suggested that this was due to inadequate levels of essential amino acids.

In a second experiment (George and Elliot, 1986) raw pigeonpea meal was substituted at up to 400 g/kg of a commercial layer diet. Egg production and feed intake were monitored over eight weeks in pullets during their peak laying period. No significant differences in egg production were noted and the health and feed intakes of the birds were not affected by increasing the rate of pigeonpea included in the diet (Table 6).

Again all diets were formulated to meet the nutrient requirements of the laying bird using a practical least cost formulation program.

It would appear from these results and reports in the literature that pigs are more susceptible than poultry to

Table 6. Mean egg production and feed intakes of laying pullets fed diets containing varying levels of raw pigeonpea.

Parameter	Level of raw pigeonpea inclusion, g/kg				SE
	0	200	300	400	
Laying %	73	79	75	72	6.4
Egg weight, g	53.2	55.3	49.8	54.3	4.2
Feed intake, g	110.4	119.4	116.6	115.2	10.4

the antinutritive factors present in raw pigeonpea. It has been shown previously that there are species differences with regard to the activity of protease inhibition (Holm and Krogdahl, 1982) and it may be invalid to predict trypsin or chymotrypsin inhibitor activity for poultry using other than avian pancreatic enzymes.

The diets formulated to a least cost program do, however, reveal one particular restriction in the use of high levels of pigeonpea meal in diets for poultry. As the level of pigeonpea increases so must the level of supplementary lipid to achieve an adequate concentration of metabolizable energy in the diet.

In general lipid supplements are costly and present problems in handling and storage, particularly in tropical regions. In this respect the combination of pigeonpea meal with rice pollard, which is relatively rich in essential fatty acids and the sulphur-containing amino acids, needs evaluation.

In conclusion it would seem that raw, ground pigeonpea presents a valuable energy and protein source in poultry diets and can be included at up to 450 g/kg of the dietary dry matter without adversely affecting the health or productivity of the bird.

Forage

As mentioned in the introduction pigeonpea has been successfully used as a forage. This forage has often been from crop left in the field after everything else is harvested or produced where there are extensive areas available for browsing (Krauss, 1932). We now examine the feasibility of intensive utilization of pigeonpea as a forage crop.

Forage for ruminants. Wijnberg (1983) has reviewed the forage quality of pigeonpea and concluded that leaf nitrogen levels are consistently high with an average of 2.9% from five separate experiments. Leaf nitrogen levels of pigeonpea were higher at grain maturity than soybean, probably due to the perennial habit of the crop and its lower leaf senescense.

From reports of grazing trials it is clear that although high levels of animal production are possible from pigeonpea forage, with 6.2 kg/ha/day reported for cattle (Akinola et al., 1975a) and 3.34 kg/ha/day for goats (Bint and Norton, 1982), there appear to be limitations to intake and hence liveweight gain when pigeonpea forage is the sole source of feed.

However, the high protein content of pigeonpea leaves suggests that the optimum use of the crop for forage would be as a supplement to low quality forage such as rice or wheat straw or as the protein source for concentrate diets. The perennial habit of the crop makes it invaluable as a standover high protein fodder for those times of the year when protein shortage is the major limit to production. Work in this area at the University of Queensland, comparing various legume straws as supplements to a basal diet of rice straw, is currently underway.

Harvest trash, including pods, cracked seed, and leaves, has also been found to be palatable to stock, and even though the protein content of this material is low, inclusion of trash up to 500 g/kg of the ration improves overall digestibility and intake of accompanying low quality hays (Quirk, 1979).

Dual purpose forage and grain. The only study to report on the use of pigeonpea as a dual forage and grain crop is that of Wijnberg (1983). In this study, various defoliation and grazing treatments by goats were applied to a short statured early maturing pigeonpea cv QPL 4. It was concluded that grazing at any stage of growth, such as prior to flowering, at pod fill, and after seed harvest, was detrimental to yield and caused plant mortality leading to low productivity in the long term. It was clear that grazing seed crops that have failed due to drought, insect damage or other stresses may be a viable option.

In the rice-based systems, it may be possible to grow a seed crop after rice and ratoon the crop for forage production. Because of the severe limits imposed by the environment, such as low moisture availability, and low temperatures, the forage production of such systems may be poor. However, in many cases the pigeonpea would survive over the dry season and rapidly regrow on the early storms of the next wet season to provide a useful supplementation for grazing at a difficult stage of the feed year.

In addition there are extensive areas in Nepal and elsewhere where pigeonpea is grown on large bunds between paddy fields. It is possible that these form an important source of seed in the rice-based system and might be profitably left for browsing. Vegetative growth would be expected to be luxuriant if the crop was allowed to grow into the "summer" months as the photoperiod would normally be relatively long and the temperature high (Ariyanayagam, 1981).

Other Uses of Pigeonpea

Many other uses of pigeonpea have been reported. These include its use as a green manure crop, an important source of firewood in some regions, as wood for light construction and basket making, as a crop for raising lac producing insects, and for medicinal purposes. These have been reviewed by Norton (1976) and Whiteman and Morton (1981).

CONCLUSION

Pigeonpea has many potential advantages for use in smallholder livestock production systems as pigeonpea can be grown as a seed crop, a forage crop or as a dual purpose forage and seed crop. It is a perennial crop that can be grown like an annual, it has drought tolerance, and it is capable of very high seed and forage yields. As a result of its diversity of phenology, its perennial habit, and its bushy growth the crop can fit into many cropping systems including sole cropping, intercropping, hedge rows, wheat rotations, and rice-based cropping systems. This diversity of uses provides a challenge to pigeonpea scientists improving this crop, but means that they must develop a carefully thought out program to meet the particular requirement of the farmers who will use the crop.

Factors which should be considered by breeders in producing improved pigeonpea varieties for smallholder livestock production systems include the ratoonability of the crop in relation to the seed and forage produced, the effect of the crop's phenology on its response to cropping practices, the feed quality of the seed and forage, the crop's plant architecture, and the need to stabilize crop yields by providing resistance to debilitating biotic and abiotic stresses.

Relatively little research has been conducted on pigeonpea as a dual-purpose crop but the evidence available on the potential of this crop strongly suggests that further work along this line will be well rewarded.

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