Linking Research and Marketing Opportunities for Pulses in the 21st Century

Proceedings of the Third International Food Legumes Research Conference

Edited by

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SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.

TOWARDS THE MORE EFFICIENT USE OF WATER AND NUTRIENTS IN FOOD LEGUME CROPPING

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Abstract

Nutrient imbalance and soil moisture stress are the major abiotic constraints limiting productivity of cool season food legumes. These constraints are more pronounced in the semi-arid tropics and sub-tropics which are the principal production zones of chickpea, lentil and faba bean. The legumes are generally grown on residual moisture as a mono crop and consequently face drought especially during the reproductive phase. In recent years, chickpea, lentil, peas and faba bean have been grown in some areas with an irrigated/assured water supply under intensive cropping to sustain cereal based systems.

An increased water supply favourably influences productivity in dry environments. Faba bean, French beans and peas show a relatively better response to irrigation. The pod initiation stage is considered most critical with respect to moisture stress. Excessive moisture often has a negative effect on podding and seed yield. Eighty to ninety percent of the nitrogen requirements of leguminous crops is met from N_2 fixation hence a dose of 15-25 kg N ha^{-1} has been recommended. However, in new cropping systems like rice-chickpea, higher doses of 30-40 kg N ha^{-1} are beneficial. Phosphorus deficiency is wide spread and good responses occur to 20 to 80 kg P_2O_5 ha^{-1}, depending on the nutrient status of soil, cropping systems and moisture availability. Response to potassium application is localized. The use of 20-30 kg S ha^{-1} and some of the micronutrients such as Zn, B, Mo and Fe have improved productivity. Band placement of phosphatic fertilizers and use of bio-fertilizers has enhanced the efficiency of applied as well as native P. Foliar applications of some micronutrients have been effective in correcting deficiencies. Water use efficiency has been improved with some management practices such as changed sowing time, balanced nutrition, mulching and tillage.

INTRODUCTION

Food legumes are an important and cheap source of protein for human and animal nutrition in developing countries. Their importance as a builder and restorer of soil fertility has long been recognized in the semi-arid tropics and subtropics and they continue to be components of subsistance cropping in Asia, Africa, Oceania and South America. Cool season food legumes viz. chickpea, pea, lentil, faba bean French bean, and grasspea together share 40%of total food legume area (Pala et al. 1991).

The productivity of cool season food legumes is often constrained by moisture scarcity and nutrient imbalance especially in the semi-arid tropics and subtropics. In some areas, such as the highlands of Ethiopia, lowland areas of south east Asia, coastal areas around the Mediterranean and water harvesting catchment areas, the highlands in West Asia and North Africa (WANA), ephemeral water logging limits productivity of these legumes (Saxena et al. 1994). In most parts of the world, food legumes are generally grown in marginal and submarginal lands which are impoverished of plant nutrients and their yield potential is not realized. The ability to fix atmospheric nitrogen enables legumes to meet a large proportion of their N-requirement provided moisture and nutrient status of the soil are favourable for the host plant and the rhizobia. Soil moisture is the most scarce input in the semi-arid tropics and management practices to improve its use is the key to an enhanced production. In this paper we review the responses of cool season food legumes to water supply and plant nutrients, interactive effects, biofertilizers, beneficial effects of legumes in cropping systems and management practices to improve the efficiency of these inputs.

R. Knight (ed.), Linking Research and Marketing Opportunities for Pulses in the 21st Century, 355–368.

FOOD LEGUMES IN CROPPING SYSTEMS

The ability of legumes to fix nitrogen, improve soil health and perform better than many other crops under harsh climatic and edaphic conditions has made them important components of subsistence cropping in the semi-arid tropics for many centuries. The beneficial effect on succeeding cereals has been well established. Kacemi (1992) reported that in Morocco, wheat grown after legumes had higher grain yields and water use efficiency (Table 1). The yield of faba bean was 2.95 t ha^{-1} as against 1.08 t ha^{-1} under continuous wheat. Chickpea and lentil also showed a beneficial effect. The evapotranspiration (ET) under different cropping systems did not vary significantly but the water use efficiency (WUE) after legumes and fallow was better. Meena and Ali (1985) working on rice-based cropping systems observed that on sandy loam soils of Kanpur (India) lentil, fieldpea, chickpea and kidney bean improved the productivity of rice 0.4 to 0.8 t ha^{-1} as compared to wheat-rice system with the kidney bean showing the most favourable effect. Similar observations were made by Ahlawat et al. (1981). The effects have been quantified in terms of nitrogen equivalent and in most studies were 25-30 kg N ha^{-1}. The benefits are not due solely to N fixation but to increased nutrient availability, reduced incidence of disease, increased mycorrhizal colonization, etc. (Wani and Lee 1995).

Table 1. Grain yield of wheat (t ha^{-1}), water use and water use efficiency as affected by previous crop (Morocco)1991 Source : Kacemi (1992)

Rotation	Wheat grain yield	ET[1]	WUEG[2]	WUEDM[3]
Wheat-Wheat	1.08	245	4.4	21.7
Wheat-fallow	2.48	244	10.2	27.1
Wheat-corn	1.81	244	7.4	25.5
Wheat-chickpea	1.95	247	7.9	24.7
Wheat-fababean	2.09	243	8.6	29.6
Wheat-lentil	1.43	238	6.0	26.3
LSD(5%)	0.40		2.1	5.1

1 ET = evapotranspiration 2 WUEG = Wheat grain yield water use efficiency

3 WUEDM = wheat dry matter yield water use efficiency

The legumes are grown in cropping systems as a sole crop and as an intercrop both under mono as well as sequential cropping systems depending upon the availability of soil moisture and domestic needs. In the rainfed areas of south and central Asia, North Africa and the Mediterranean these crops are largely grown on conserved soil moisture as a monocrop. In the rainfed areas of India, Bangladesh, Nepal and Pakistan, intercropping of chickpea and lentil with mustard, linseed and barley is popular. In peninsula India, chickpea/safflower is also an important intercropping system. The practice of intercropping is primarily for diversified and stable production. In the subhumid central Alberta, barley intercropped with field pea is profitable. This system also returned more nitrogen to the soil than a monocrop of barley (Izaurralde 1990).

In recent years, new varieties and attractive prices have led to the cultivation of legumes in irrigated areas in intensive systems. For example, French bean (kidney bean), has been introduced as a new winter crop in the north-east plains of India in a maize-cowpea-mungbean system (Ali and Lal 1991). Chickpea and Lentil are also grown under double cropping with rice in eastern India, Bangladesh and Nepal. On uplands of Pakistan and India maize-chickpea, maize-peas and maize-lentil are important rotations whereas in the semi arid tropics of Morocco, faba bean-wheat, chickpea-wheat and lentil-wheat are important. In south-east Asia, relay cropping of grasspea and lentil with short duration rice is practised on low land to use the residual moisture. In the Mediterranean region of Central Asia, winter-sown lentils and chickpeas were distinctly superior to spring-sown crops, which often face terminal drought.

NUTRIENT MANAGEMENT

Plancquaert (1991) showed that under good conditions, a crop of faba bean producing 6.5 t ha^{-1} may remove 405 kg N, 102 kg P_2O_5 and 258 kg K_2O ha^{-1}. Since the soil of the major pulse producing regions are impoverished of plant nutrients, an adequate and balanced fertilization is necessary to boost productivity. The ability to fix N_2 enables leguminous crops to meet a large proportion of their nitrogen requirements. Huber et al. (1987) at Zurich found that faba bean fixed on an average 90% of its N-requirement. A well-managed crop of chickpea may fix up to 270 kg N ha^{-1} (Nutman 1969). Since food legumes are harvested as grain, the amount of N in the crop residue and left on the soil does not replenish the N removed by the crop. It is imperative therefore to enhance nitrogen fixation or resort to N-fertilization in the already poor soils of the semi-arid tropics and subtropics (Buresh and Datta, (1991).

Inoculation and Nitrogen

Inoculating seed with an appropriate rhizobial strain increases nodulation, nitrogenase activity and yield (Whiting 1985, El Khadir 1991, Reddy 1992, Srivastava 1993 and Haque and Haq 1994). In the All India Co-ordinated Pulse Improvement Project (AICPIP), seed inoculation enhanced the productivity of chickpea and lentil by 10-15% in different parts of India (Chandra and Ali 1986). In the semi-arid regions of Morocco inoculation increased the seed yield of faba bean by 80% over the check (Table 2).

Table 2 Effect of N application (120 kg N ha^{-1}) and rhizobium inoculation on chickpea nodulation and grain yield, Morocco 1990-91

Treatment	Number of nodule/plant	Nodulation index	Grain yield (t ha^{-1})	% increase
N check	5.0	2.0	1.36	74
Untreated	2.2	1.5	0.78	-
Inoculated	23.5	4.0	1.40	80

Source : El Khodir (1991)

Strains of rhizobia are not equally effective and it is necessary to use specific strains to enhance fixation. Tekalign (1994) reported on the rhizobial strain specificity of faba bean and lentil in Ethiopia.

Legume species not only differ in their nodulation but cultivars within species also differ significantly, suggesting host factors are determinants of assimilation. Significant interactions of rhizobial strain x genotypes have been observed for chickpea by Patel et al. (1986) in central India. They observed that in genotype BG 209, strain KG 31 was most effective whereas in Dohad Yellow, F 75 and in Chaffa, H 45 were the most effective strains (Table 3). Similar interactions have been reported for peas and faba beans under Australian conditions (Herdina and Silsbury 1989).

In view of biological nitrogen fixation, a starter dose of 15-30 kg N ha^{-1} has been recommended for normal sown rainfed legumes. The French bean crop on the north-east plains of India, however, needed 100-120 kg N ha^{-1} to realize its yield potential, as the native rhizobial strains were not effective (Fig. 1). Similarly in rice-based cropping systems on low lands, late-sown chickpea generally responds well up to 40 kg N ha^{-1} (Ali and Mishra 1996). Under irrigated conditions, peas and faba bean also show good responses to increased nitrogen level up to 40 kg N ha^{-1}.

Table 3. Effect of Rhizobium inoculation on the grain yield (t ha^{-1}) of four genotypes of Kabuli chickpea.

Rhizobium strain	Genotypes BG 209	Dohad Yellow	JG 315	Chaffa	% increase over control
F 6	3.02	3.10	3.49	2.93	49
Ca 181	2.78	3.02	3.49	2.62	42
KG 31	3.17	2.54	4.24	1.89	41
F 75	3.10	3.17	4.44	2.54	58
H 45	2.54	2.94	3.41	2.41	41
Uninoculated control	1.91	1.91	2.62	1.98	-

LSD(P=0.05) Genotypes(G) 0.34; Rh. strain(S) 0.14; G x S 0.29

Source : Patel et al. (1986)

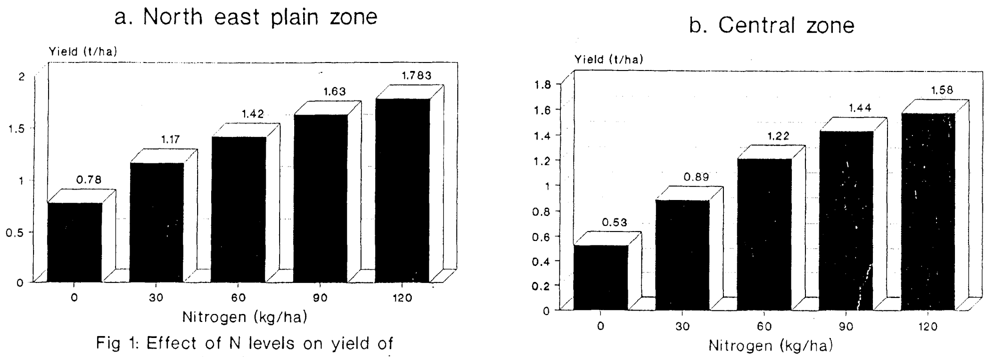

Fig 1: Effect of N levels on yield of frenchbean

Phosphorus Effect of Rhizobium inoculation on the grain yield (t ha^{-1})of four genotypes of Kabuli chickpea.

For most crops, P is the second most critical plant nutrient but for legumes it is the first. Besides metabolic functions, P has a role in root proliferation, nodule development and biological nitrogen fixation. Phosphorus deficiency is wide spread in South Asia and Africa. Tandon et al. (1992), found that out of 371 districts in India, 150 were low in P status while only 17 showed K deficiency. Khanom and Islam (1984) reported that on calcareous brown flood soils of Bangladesh an application of 60 kg P_2O_5 ha^{-1} significantly improved chickpea yields. On grey flood plain soils of Jamalpur (Bangladesh), a response was observed up to 90 kg P_2O_5 ha^{-1} (Islam 1989). In the WANA region, lentil showed a good response to 48 kg P_2O_5 ha^{-1} (Singh and Saxena 1986). Under Pakistan conditions, Malik et al. (1991) found that lentil responded up to 40 kg P_2O_5 ha^{-1}. On a sandy loam soil of Delhi (India), an application of 60 kg P_2O_5 ha^{-1} significantly increased yield, nodulation and nitrogen assimilation in peas (Kasturi 1995). In the semi-arid regions of Morocco, the yield of winter chickpea increased by 10-48% with application of 60 kg P_2O_5 ha^{-1} depending upon moisture availability and P status of soil. Yield responses were higher on soils testing low in P (EL Khadir, 1991).

Potassium

The K status of soils of the semi-arid tropics and subtropics is generally high, however, in coarse textured and acidic soils which do not contain illite clay minerals, a deficiency of K have been observed. Response to K application has been recorded in laterite, red, coastal and deltic alluvial soils of India (Khera et al. 1990). Results of AICPIP trials on lentil showed that in the north-east plains of India, an application of 20 kg K_2O ha^{-1} increased mean yield by 219 kg ha^{-1} but in the north-west plains, there was no response (Ali et al. 1993). Responses to a high dose of K have been reported from Egypt. El Fouly et al. (1989) observed that faba bean responded to 120 kg K_2O ha^{-1}. From 8 experiments, the mean increase in yield was 9% over the control when 120 kg K_2O ha^{-1} was applied. This is an exceptionally high dose and limited to a specific location.

Secondary nutrients and micronutrients

Among the secondary nutrients, sulphur appears to be most important. In general, the S uptake by legumes is almost double that of cereals for each unit of grain production. Further, sulphur containing amino acids like methionine, cystein and cystine are low in legumes and therefore an adequate sulphur fertilization is important. Sulphur deficiency has been reported for light textured soils in India. In the multilocation studies of AICPIP, applications of 20 kg S ha^{-1} increased yield of chickpea and lentil by 0.3-0.6 t ha^{-1} in northern India (Fig. 2). The light textured soils of the north-west plains showed greater responses. Applications of S beyond 20 kg S ha^{-1} did not prove beneficial (Ali and Singh 1995). However, on sulphur deficient soils of Ludhiana (north-west plains of India), Aulakh and Pasricha (1986) reported that application of 40 kg S ha^{-1} increased yields of lentil by 27% over the control. Among micronutrients, responses to Zn, Mo, B and Fe have been reported from different parts of India. In the calcareous clay loam soils of the foot hills of Shiwalike range, wide spread deficiencies of Zn have been observed. Among the crops, lentil has been found most sensitive to Zn deficiency. Soil applications of 12.5-15.0 kg ZnSO$_4$ ha^{-1}or foliar spray of 0.5 kg ZnSO$_4$ ha^{-1} twice (15 and 45 days after sowing) corrected Zn deficiency and increased yield. (Gangwar and Singh 1986). Different responses of genotypes to nutrient stress have been observed (Sakal et al. 1982). On sandy loam calcareous soils of north Bihar (India) which are deficient in iron and boron, lentil genotype L 4076 performed better than Precoz sel. Seed treatment with aqueous solutions of ferrous sulphate increased the yield of Precoz sel by 33.8% whereas L 4076 did not respond (Sinha 1988). In another study, variety DPL 77-2 was found tolerant to Zn deficiency and PL 406 to Fe stress (Singh et al. 1984). Responses of chickpea to foliar spray of 2% FeSO$_4$ on calcareous soils of southern India have also been observed (Perur and Mithyantha 1985). These results suggest a breeding program aimed at transferring genes from tolerant land races/cultivars may help alleviate micronutrient disorders.

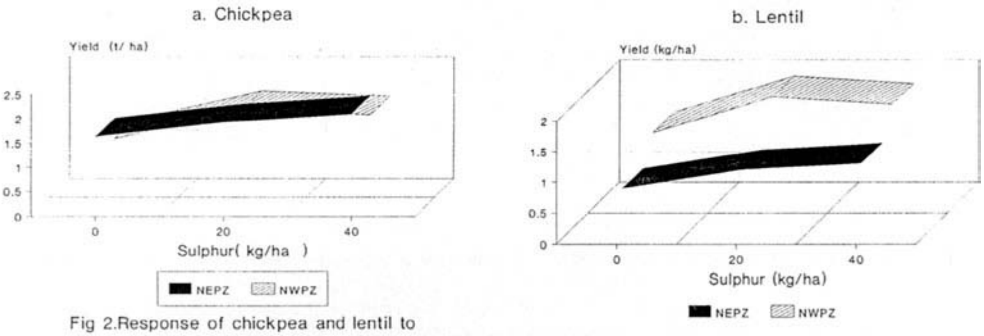

Fig 2.Response of chickpea and lentil to sulphur fertilization

Molybdenum being an essential component of the nitrogenase enzyme, has a role to play in N_2- fixation. Several workers have reported significant increase in yields of pea (Srivastava and Ahlawat 1995), lentil (Sharma and Chahal 1983), chickpea (Pal 1986) and faba bean (Brhada 1986) with applications of 1.0-1.5 kg sodium molybdate ha^{-1}. Ali and Mishra (1997) at Kanpur, India found foliar sprays of 0.01% ammonium molybdate increased yields of Kabuli chickpea by 0.38 t ha^{-1} (Table 4). A response to boron was also observed. Foliar application of 0.2% borax enhanced grain yield by 0.59 t ha^{-1}.

Table 4 Effect of foliar spray of Molybdenum (0.01% Ammo. Molybdate) and Boron (0.2% borax) on seed yield (t ha^{-1})of Kabuli Chickpea genotypes (Kanpur, India).

Foliar Nutrition	Genotypes				Mean
	BG 267	BG 1003	HK 89-96	L550	
Water spray	1.26	1.06	1.04	1.36	1.18
Molybdenum spray	1.66	1.59	1.48	1.52	1.56
Boron spray	1.76	1.64	1.73	1.94	1.77
Mean	1.56	1.43	1.42	1.61	
	Genotype	Foliar spray	Interaction		
SE mean	0.07	0.04	0.09		
LSD (P=0. 05)	0.15	0.13	NS		

Source : Ali and Mishra (1997)

The genotypes did not show different responses. Similar results have been obtained in other countries (Khanom and Islam 1984).

Improving nutrient use efficiency

Mineral nutrient stresses are a wide spread constraint to food legume production in the semi-arid tropics and sub-tropics. Water being a solvent and carrier of mineral nutrients, plays a role in fertilizer use efficiency. In dry areas, the amount of fertilizers to be applied is dictated by water availability in addition to edaphic factors. For example, irrigated chickpea in north India responded favourable up to 80 kg P_2O_5 ha^{-1} whereas under rainfed conditions the response was limited to 30-40 kg P_2O_5 ha^{-1} (Ali 1994).

Method of nutrient application

The methods of application and the mobilization and fixation dynamics of the soil influence the efficiency of applied nutrients. Band placement of phosphatic fertilizers is more efficient than broadcasting and mixing due to the low mobility and fixation of P-ions. Studies at ICRISAT showed that in vertisols of south India, deep banding (15 cm) of 10 kg P ha^{-1} was as effective as mixing 20 kg P ha^{-1} in rainfed chickpea (Arihara et al. 1991).

Under rainfed conditions, when dry top-soil layers do not permit top dressing of basal applications of fertilizers, foliar sprays may supply small amount of macronutrients. Several studies under AICPIP revealed that under dryland conditions foliar sprays of 2% urea and di-ammonium phosphate enhanced productivity of chickpea (Ali 1994). Foliar nutrition of micronutrients corrects nutritional disorders rapidly. Gangwar and Singh (1986) working at Pantnagar (India) reported that on calcareous clay loam soils, foliar sprays of 0.50% $ZnSO_4$ mixed with 0.25% lime at 15 and 45 days after emergence of lentil were more efficient in correcting Zn deficiency than a basal application of 10 kg $ZnSO_4$ ha^{-1}

Soil micro-organisms :

Rhizobium spp, *Bacillus* spp. and Vesicular Arbuscular mycorrhizae (VAM) are involved in the nutrition of food legumes. The proliferation and colonization of these micro-organisms, the growth of the host plant and the rhizospheric environment (nutrient status, moisture, aeration etc.) are interdependent. In a study conducted at Ludhiana (India), seed inoculation of lentil coupled with an application of 20 kg P_2O_5 ha^{-1} produced yields comparable with 40 kg P_2O_5 ha^{-1} without inoculation (Dhingra et al. 1988). It is commonly accepted that soil micro-organisms can stimulate the mycelial growth of mycorrhizal fungi, which may increase the availability of phosphorus (Bieleski 1973).

The role of phosphate-solublizing bacteria (PSB) in P nutrition is well recognized. Their ability to enhance P availability of less expensive citrate soluble phosphatic fertilizers, like rock phosphate, is a boon to poor farmers of semi-arid regions. Rathore et al. (1992) working on vertisols of central India found that inoculation of lentil seeds with PSB (*Bacillus megatericum*) increased yields by 16% over the control. At Delhi, seed inoculation with *Bacillus polymixa* increased N and P uptake by peas. Dual inoculation with *Rhizobium* and PSB was most effective (Srivastava and Ahlawat 1995).

The symbiotic association between plant roots and fungal mycelia i.e. mycorrhiza has received attention in recent years. VAM enhances plant growth by improved mineral nutrition particularly of P, and water uptake, due to the network of hyphae originating from the mycorrhizal roots. Rao et al. (1986) observed high N and P concentrations in the shoots of chickpea due to *Glomus fasciculatum* inoculation. Reddy (1992) working on the efficacy of biofertilizers on nodulation and yield of lentil found that *Rhizobium* and VAM both improved nodulation and yield (Table 5). Thus, it is clear that VAM improves not only the P nutrition of the legumes but also that of rhizobial bacteroides and the efficiency of N_2 fixation.

Table 5 . Effect of bio-fertilizers on root nodulation (80 DAS) and grain yield of lentil (New Delhi, India)

Bio-fertilizers	No. of nodules per plant	Wt.of nodules ($mg/plant^{-1}$)	Grain yield ($t\ ha^{-1}$)	
			1989-90	1990-91
Control	17.5	4.2	0.84	0.80
Rhizobium	26.1	5.4	1.03	0.98
VAM fungi	20.5	6.3	1.09	1.01
Rhizobium +VAM fungi	29.8	7.2	1.19	1.14
LSD. (P=0.05)			0.04	0.05

Source : Reddy (1992)

Positive interactions

An understanding of the positive interactions among mineral nutrients, soil micro-organisms and organic manures may improve the efficiency of applied fertilizers. Enhancing the growth and colonization of *Rhizobium* spp. and reducing fixation/leaching losses of mineral nutrients due to organic manuring and residue management are well recognized. Prasad et al. (1990) working on a rice-lentil system at I.A.R.I., New Delhi reported that resulting from the incorporation of lentil residues, 46-89 kg ha^{-1} of primary nutrients (15-36 kg N, 2.5-10.0 kg P_2O_5 and 28.5-43 kg K_2O) were saved and thereby the soil nutrient balance improved.

An application of molybdenum improves nodulation, fixation and yield as Mo is a constituent of the enzyme nitrogenase. Mohandas (1985) reported that soaking seeds of French bean in 2 ppm sodium molybdate for 1 hour increased nodulation, N uptake and yield. A similar synergistic effect of 0.5 kg Mo ha^{-1} was noticed on peas by Srivastava and Ahlawat (1995). Pal (1986) observed that in the presence of P, the efficiency of applied Mo improved. Phosphorus application improves the N_2-fixation in legumes and uptake of several other nutrients due to its active role in root proliferation. The P x S interaction is generally positive at low to medium levels of applied P but at higher level of P, the effect is antagonistic (Nayak and Dwivedi 1990). Significant interactions of P and B in lentil have also been reported (Singh and Singh 1983).

WATER MANAGEMENT

Crops grown on conserved soil moisture, often face moisture stress during growth. In the Mediterranean region, crops sown in spring also face stress. In some regions, like northern Europe and the central and eastern highlands of Ethiopia, excessive soil moisture may adversely affect productivity. The problem of excess moisture is also experienced on deep vertisols of south India as well as coastal regions where the rainfall is bimodal. However, the extent of the moisture scarcity problem is far greater than moisture excess.

Responses to irrigation

Cool season food legumes generally respond to limited irrigation. Studies carried out at ICARDA, Tel Hadya (Syria) on chickpea showed a linear response to moisture for seed yield and total biomass (Saxena and Saxena 1991). The yield from plants with adequate moisture was three times that of the rainfed treatment. Rizk and Hassan (1991) reported that the average seed yield of lentil in Sharkia Governerate of Egypt increased from 1.36 t ha^{-1} without irrigation to 2.01 t ha^{-1} with irrigation at 20 and 50 DAS. Studies in agro-ecological zones of India revealed that chickpea, lentil, peas and French bean responded to irrigation in the central and southern zone. French bean was the most responsive followed by field pea. Late sown chickpea showed a better response to irrigation than a normal sown crop (Ali 1994). Beneficial effects of supplemental irrigation in spring and winter season chickpea in Syria (Saxena, 1992), and winter sown lentil in Bangladesh (Hassan and Rahman 1987) have been reported. Srivastava and Srivastava (1992) working in the plateau region of north Bihar (India) found that the irrigation was the most important input contributing 45-50% towards productivity. Responses have also been reported from Europe. In Poland, irrigation increased the productivity of faba bean and peas by 47.4% and 20.9% respectively over the controls (Borowezak and Szukala 1991).

When scheduling irrigation, various approaches have been advocated, such as crop day, phenological stage, day interval and cumulative pan evaporation. The reproductive phase particularly pod development is the most critical with respect to moisture stress and irrigation at this stage has given higher yields. Mohamad et al. (1988) in Sudan observed that the omission of one irrigation at the reproductive phase of faba beans reduced pod development and seed yield whereas missing an irrigation during the vegetative phase did not have a negative effect (Table 6). The initial moisture profile and soil type influences the requirement for irrigation. For example, on light soils of Kanpur (India), irrigation at maximum branching was as important as at pod development (Ali 1991). Kasturi (1995) working on peas at Delhi (India) observed that moisture stress in the vegetative stage was most detrimental for nitrogenase activity and nodule production. Tiwari and Tripathi (1995) working at Raipur (India) reported that chickpea grown in rice fallows needed irrigation at branching and at podding. Similarly in lentil, a 51% increase in yield was recorded with irrigations at branching and podding (Rathore 1992). Dhar and Singh (1995) used cumulative pan evaporation data to schedule irrigation of chickpea on a silty clay loam soil of Pantnagar (India). They found that irrigation scheduled at IW/CPE ratio of 0.6 gave a higher yield and WUE than other treatments (Table 7). The yield response was higher during the dry year of 1989. Studies on scheduling irrigation on the basis of day interval in the Sudan showed that a 7-days interval was the most productive for faba bean. In another study, Mohamad et al. (1988) reported that irrigation at a 15-day interval was most economical and efficient in faba bean. Studies in French bean in the north-east plains and central zone of India showed that the 25-day crop stage was most critical for irrigation (Ali and Lal 1991). The mean increase in productivity from irrigation at this stage was 2.1 t ha^{-1} in NEPZ and 0.4 t ha^{-1} in the central zone. The crop responded to 3-4 irrigations (Fig 3). In Egypt, the 30-day crop stage was found to be most critical for irrigation of lentil (Attia 1988).

Table. 6 Effect of water stress during stages of plant growth on grain yield (t ha^{-1}) of faba bean at 3 locations in Morocco

Treatments	Yield Hudeiba	Shambat	Wad Madani
1. Irrigation every day	2.57	1.85	0.97
2. Irrigation every 15 day	1.92	1.89	0.64
3. As (i) but 3rd irrigation missing			
4. As (i) but 7th irrigation missing	1.38	2.02	0.68
5. As (i) but 9th irrigation missing	2.02	1.96	0.80
6. As (i) but 3rd and 7th irrigation missing	1.55	1.85	0.59
7. As (i) but 7th and 9th irrigation missing	1.39	1.65	0.56
8. As (i) but 3rd and 9th irrigation missing	1.98	1.54	0.64
9. As (i) but the 3rd, 7th and 9th irrigation missing	1.37	1.65	0.51
Mean	1.86	1.99	0.71
SE	0.08	0.11	0.06

Mohamad et. al. (1988)

Table 7. Effect of irrigation on seed yield (t ha^{-1}) of lentil and water use efficiency (kg grain ha^{-1}- cm) (Pantnagar, India).

Irrigation at IW/CPE	Seed yield		Water use efficiency	
	1989-90	1990-91	1989-90	1990-91
0.4	1.85	1.08	66.3	51.8
0.6	2.02	1.46	74.2	59.0
0.8	1.92	1.31	51.6	39.6
No irrigation	1.93	0.96	68.5	43.5
LSD(P=0.05)	0.33	0.34		

Source : Dhar and Singh (1995)

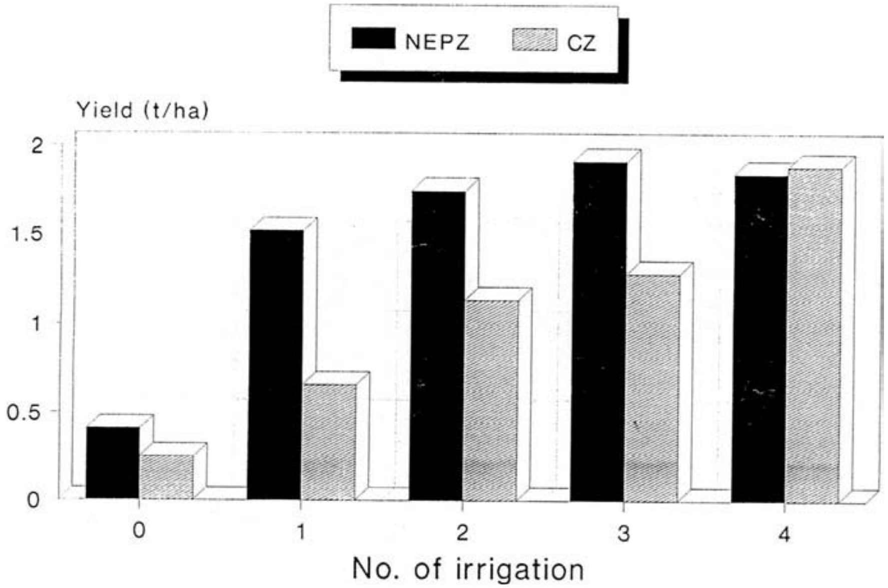

Fig 3. Response of frenchbean to irrigation

Excessive moisture

Excessive moisture, from poor drainage leads to crop damage from the anaerobic conditions, accumulation of toxic acids, reduction in mineral nutrient availability, inhibition of nitrogen fixation and increased susceptibility to root diseases. In the Ethiopian highlands, the problem is acute. Sowing on broadbed and furrows considerably increased the yield and economic return of chickpea, lentil and faba bean. Field observations in Egypt have also revealed that broadbed and furrow systems improved the productivity of irrigated lentil on the heavy soil of the region by preventing the transient water logging which is common feature in basin irrigation (Saxena et al. 1994).

In some crop species genotypic differences exist in response to anoxia. Alcalde and Summerfield (1994) subjected pot grown plants of two genotypes of lentil to water logging for 2,4 and 6 days after 15 days of emergence. The genotype Pant L 406 was better nodulated and developed more extensive root system than variety Precoz under water logging conditions. Genotypic variation with respect to anoxia needs to be exploited in breeding programs.

Efficient use of water

In-situ conservation of rainwater and the efficient use of conserved as well as irrigation water are keys to enhanced productivity. Various practices such as improved tillage, choice of appropriate crop and variety, sowing time/season, use of balanced and adequate plant nutrients, weed management, use of mulches, anti-transpirants etc. influence productivity and water use efficiency. In dryland areas, where the top layer of soil may be dry at the beginning of the season, a technique to place seeds in the moist zone to establish a good plant stand is important. A low water use efficiency in dryland areas is commonly associated with low yields on account of a low plant population. In the drier regions of central India, deep sowing of chickpea (10-12 cm) is practised to ensure contact of seed with moist soil.

Shifting the cropping season, according to evaporative demand of a region, is another way of improving the use of available water. An example is the winter cultivation of chickpea in the WANA region. Chickpeas are normally sown in spring on the residual soil moisture supply, which decreases with the growth of the crop. The crop faces drought in its late vegetative or reproductive stages because of increasing evaporative demand. Shifting the cropping season from spring to winter and growing an appropriate variety has led to increase in yield and WUE (Table 8). The mean increase in productivity was 87%. The effect was most pronounced at locations where seasonal rainfall was low.

Table. 8 Chickpea grain yield (t ha^{-1}) for winter and spring sowing at four locations in Morocco 1988-1991.

Location	Av. seasonal rainfall (mm)	Av. yield winter	spring	% difference
Douyet	451	2.93	1.79	64
Merchouch	388	1.81	0.99	83
Jemma Shaim	305	2.56	1.26	103
Jemaa Riah	277	1.20	0.52	131
Mean		2.13	1.14	87

Water Use efficiency

An adequate and balanced nutrition improves WUE, primarily due to a greater seed yield. However, potassium being involved in stomatal regulation helps reduce transpiration losses and consequently increases crop yield and WUE. Results of field experiments at Kanpur (India) showed that foliar sprays of 2% KCl at flowering increased grain yield and WUE of chickpea. WUE, with foliar sprays of KCl was 16-17 kg grain ha^{-1} -

mm water as compared to 14-15 kg grain ha^{-1} -mm water in the control (Ali 1985). Abd-Alla and Wahab (1995) working on water stressed faba beans found that applying KCl at 150 mg kg^{-1} soil, helped alleviate moisture stress and enhanced N fixation. The use of `Jalshakti', a water absorbing polymer is also promising in increasing moisture availability. At Kanpur (India), soil incorporation of Jalshakti at 12 kg ha^{-1} or furrow placement at 2 kg ha^{-1} at sowing enhanced yield of chickpea by 12% over the control Ali (1994) (Table 9).

Table 9 . Effect of Jalshakti on yield (t ha^{-1}) of chickpea (Kanpur, India)

Jalshakti	Grain yield
Soil incorporation 8 kg ha^{-1}	2.77
Soil incorporation 12 kg ha^{-1}	2.70
Furrow placement 1 kg ha^{-1}	2.72
Furrow placement 2 kg ha^{-1}	2.95
Harrowing (dust/mulch)	2.89
Control	2.63
LSD (P=0.05)	

Source: Ali (1994)

The effect of phosphorus in increasing water use and root proliferation is well recognized. Venkateswarlu and Ahlawat (1993) working on phosphorus x irrigation interactions found that the response of applied P in the presence of irrigation, was much higher than under unirrigated conditions. The yield of lentil with the application of 70 kg P_2O_5 ha^{-1} was 1.55 t ha^{-1} when irrigation was scheduled at 0.6 IW/CPE ratio whereas at low moisture regime (0.35 IW/CPE ratio) it was 1.43 t ha^{-1} and under unirrigated conditions 0.75 t ha^{-1} (Table 10). Khera et al. (1991) working on P nutrition under irrigated and rainfed conditions of southern India reported that on vertisols an application of 52 kg P_2O_5 ha^{-1} under irrigated conditions increased yields of chickpea by 1.68 t ha^{-1} whereas in the absence of P, the yield increment was only 1.19 t ha^{-1}

Table 10 Effect of soil moisture and phosphorus on seed yield (t ha^{-1}) of lentil (New Delhi, India)

Soil moisture (IW/CPE ratio)	Phosphorus (kg P_2O_5 ha^{-1})		
	0	35	75
No post-sowing irrigation	0	0.64	0.75
Irrigation at 0.35 IW/CPE	0	1.17	1.43
Irrigation at 0.60 IW/CPE	0	1.30	1.55
LSD (P=0.05)		0.04	

PBI = Phospho bacterial inoculation Source: Venkateswarlu and Ahlawat (1993)

Increased WUE due to application of surface mulches, anti-transpirants and light reflectants have been advocated. In Syria, Saxena et al. (1992) observed increases in chickpea yields with dust mulching when the seasonal rainfall was 372 mm. Mandal and Mahapatra (1990) working on lentil/barley intercropping in the tropics of India found applying a straw mulch at 7.0 t ha^{-1} improved the yield of lentil by 11-17%. Applications of a light reflectant (Kaolin) at 100% flowering in chickpea increased yields in Syria whereas the effect on faba bean was not significant (Saxena et al. 1992). Lal et al. (1994) found a foliar spray of a 6% Kaolin suspension 80 DAS increased the relative water content of leaves and WUE in lentil.

CONCLUDING REMARKS

The importance of factors such as nutrition and water supply to the growth of cool season food legumes has been discussed above for the cropping systems of the semi-arid tropics, subtropics, and the Mediterranean regions. It was suggested the realized yields were far below potential productivity due to several production constraints.

However, detailed information is lacking and requires the attention of research scientists on the means of improving management practices which have a bearing on WUE in different production systems. Advancing the cropping season from spring to winter in the WANA region is an example of efficient crop management. Variability in the land races/genotypes with respect to their tolerance to drought has been observed and should be exploited. In the regions where excess moisture is constraining productivity, appropriate bed management techniques need to be developed.

Imbalance and an inadequate availability of plant nutrients in most regions often limits productivity. Among plant nutrients, phosphorus is most important, and good response to 30-40 kg P_2O_5 ha^{-1} in rainfed areas and up to 80 kg ha^{-1} in irrigated areas have been observed. The escalation in the price of P-fertilizers, in recent years, particularly in India, calls for efforts to improve the efficacy of P-fertilizers. Limited research has shown that band placement and use of PSB help improve the efficiency of P-fertilizers. In south Asia, sulphur deficiency has been observed widely. Applications of 20-40 kg S ha^{-1} are beneficial particularly on light textured soils having a low S status. Crop response studies have shown the beneficial effect of fertilization with micronutrients such as zinc, molybdenum, boron and iron under certain edaphic conditions. Genotypic variation with respect to zinc and iron stress has been observed. It is imperative to identify areas with deficiencies of micronutrients, to find out critical limits and to improve the efficiency of applied nutrients. Screening of germplasm to find genotypes tolerant to these deficiencies should be an important part of future research.

Most of the information on the use of nutrients in food legumes is for the component crops rather than cropping system. Since nutrient mobilization, the fixation dynamics of a soil, water availability and the nature of the preceding crops, influence the efficiency of applied nutrients, comprehensive information on fertilizer management for the whole cropping system needs to be generated. More emphasis should be given to integrated nutrient management especially for the new cropping systems in irrigated areas. Information on nutrient x water interactions are limited. A better understanding of these interactions would help improve the productivity of legumes under the existing constraints.

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