CHAPTER II

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In Chhattisgarh state, there is a good possibility of urdbean-wheat cropping system under unbundled upland Vertisols. The literature on individual crops are in plenty but considering the cropping system, practically very limited research work highlighting the planting methods and nutrient management in urdbean and their residual effect on succeeding wheat has been done in Chhattisgarh. The literature on other crops have also been included due to paucity of sufficient research work on above aspects. In this chapter, an attempt has been made to present the review of available literature in the following heads:

2.1 Urdbean-Wheat cropping system
2.2 Planting method in urdbean
   2.2.1 Effect on crop productivity
   2.2.2 Effect on nutrient content and uptake in plant
   2.2.3 Effect on soil physico-chemical properties
2.3 Nutrient management in urdbean
   2.3.1 Effect on crop productivity
   2.3.2 Effect on nutrient content and uptake in plant
   2.3.3 Effect on soil physico-chemical properties
2.4 Direct and residual effect of nutrient on wheat
   2.4.1 Direct effect of nutrient
   2.4.2 Residual effect of nutrient
2.5 Energy studies
2.6 Economics
2.1 Urdbean-Wheat cropping system

Das and Mathur (1980) reported that grain yield of wheat grown with 0-100 kg N ha\(^{-1}\) after \textit{V. mungo} in pure or mixed stands were significantly higher than when grown after maize and other legumes in pure and mixed stands. Inclusion of mungbean or blackgram in urdbean-wheat cropping system, generally increased the yield of the winter crops. The highest gross and net returns were obtained from rice/blackgram-wheat cropping system (Basak and Shah, 1993). Urdbean increased the wheat yield significantly over fallow, paddy, niger and maize crops grown in \textit{kharif} (Singh and Bajpai, 1993). Sharma \textit{et al.} (1998) reported that wheat yield was higher after maize-legume intercrops than following pure maize, with little difference between the different intercropping systems. Wheat yield averaged over treatments and years was 1.89, 2.60 and 3.07 t ha\(^{-1}\) with 0, 60 and 120 kg N ha\(^{-1}\), respectively.

Similarly, Shivram and Ahlawat, (2000a) carried out experiment with treatment comprised of 3 cropping system \textit{viz.}, pigeonpea \textit{cv. UPAS 120} - wheat \textit{cv. UP 2338}, pigeonpea + blackgram \textit{cv. T-9} (blackgram stover removed) - wheat and pigeonpea + blackgram (blackgram stover incorporated) - wheat and 3 recommended dose of fertilizers (RDF). The RDF for rainy season crops and wheat were 18 kg N + 46 kg P\textsubscript{2}O\textsubscript{5} +
20 kg K₂O + 20 kg S ha⁻¹ and 120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹, respectively. A significant increase in growth and yield attributes, and yield of pigeonpea was noted with each increment of fertilizer dose up to 100% of recommended dose. The wheat, following pigeonpea or blackgram intercropping, recorded significantly higher growth and yield attributes, and yield of wheat over wheat, following sole pigeonpea and pigeonpea or blackgram intercropping. The residual effect of fertilizers applied to preceding crops on wheat was significant up to 75% of the recommended dose. The wheat crop responded favourably up to direct application of 75% of the recommended dose of fertilizers in respect of yield attributes and yield. The highest mean net returns was obtained from pigeonpea or blackgram - wheat cropping system, where rainy-season crop and wheat were applied with 100 and 75% of RDF, respectively.

Shivram and Ahlawat (2000b) reported that the cropping system in respect of N, P, K and S uptake were in the following order: pigeonpea + blackgram - wheat > pigeonpea + blackgram - wheat > pigeonpea - wheat. The uptake of nutrients (N, P, K and S) increased up to 100 and 75% of RDF applied to rainy season crops and wheat, respectively. The pigeonpea + blackgram intercropping system recorded higher total N and available P in soil after rainy season crops
compared with the sole pigeonpea. Application of fertilizers to rainy season crops up to 75% of the recommended dose improved total N, available P and S status of soil after rainy season crops over no fertilizer. The pigeonpea + blackgram - wheat cropping system left behind higher available P in soil compared with pigeonpea – wheat system. The pigeonpea + blackgram - wheat cropping system and fertilizer application to each crop in the system recorded higher number of bacterial in soil.

2.2 Planting method in urdbean

Increasing the productivity of kharif mungbean through planting methods was tested under trial conducted at Varanasi and Hissar during 2003. At Varanasi, the ridge planting (884 kg ha⁻¹) was significantly superior to flat planting in uniform rows of 30 cm or in paired rows (20/40 cm). The raised bed sowing of mungbean was at par with ridge planting. At Hissar, the paired rows were significantly inferior to ridge planting (603 kg ha⁻¹) as well as flat planting also. In case of urdbean, planting methods showed no effect when compared to routine flat method on the basis of two years experimentation at Raipur [Anonymous, 2003].
2.2.1 Effect on crop productivity

Subramanium and Palaniappan (1981) noticed that urdbean crop grown on ridges and on flat seed beds gave similar yields. Aziz and Rahman (1986) studied with two levels of planting method, broadcast and line sowing (60 cm apart) for pigeonpea with 100% seed rate of blackgram (40 kg ha\(^{-1}\)). Line seeding showed the best performance than broadcast seeding for pigeonpea as mixed crop. Highest LER (1.27) was obtained from 15 kg ha\(^{-1}\) seed rate, which was identical with 25 kg ha\(^{-1}\) (1.26). Thakur and Bora (1987) observed that the seed yield of *V. mungo* was higher when 1 or 2 rows of *V. mungo* was intercropped with maize when grown in rows 75 cm apart than other intercropped stands and sowing pattern. Yadav et al. (1993) studied the cotton cv. JKH7-1 and hy-4 grown alone or intercropped with green gram (*Vigna radiata*), blackgram (*Vigna mungo*) or soybean in uniform (90 x 90 cm) or skipped (90 x 60 - 180 cm) rows and reported that seed cotton yield was not significantly affected by sowing pattern, but the yield of the intercrops were higher in uniform rows.

On the basis of three years experimentation on urdbean, results indicated that non monetary inputs viz. method of sowing, time of sowing and time of weed control significantly effected the growth and yield of rainfed blackgram. Improved practices out yielded local practices. The
treatment, line sowing 30 x 10 cm; onset of monsoon sowing and hand weeding at 30 DAS gave significantly higher yield of blackgram. Third week of June sowing recorded higher number of pods plot⁻¹ and higher yield (78% more over control) (Shrinivasan et al., 1997). Sarkar et al. (1997) reported that paired row sowing gave higher groundnut pod yields than uniform rows, irrespective of cropping system. Groundnut seed equivalent yield and land equivalent ratio were highest when paired rows of groundnuts were intercropped with 2 rows of greengram. This treatment also gave the highest monetary advantage.

Karam-Husain et al. (1998) also reported that mungbean (Vigna radiata) cv. T-44, urdbean (V. mungo) cv. T-9 and sunflower cv. morden when grown in pure stands or in 3:1, 6:2, 4:1 or 8:2 sunflower : legume intercrops, yield of all crops was decreased by intercropping. Sunflower equivalent yield and net monetary returns were highest from the sole crop of sunflower. Land equivalent ratio was only above 1 in the 6:2 sunflower: mungbean intercropping system.

Singh (2000) reported that the yield, land equivalent ratio, maize-equivalent yield and economic returns of a mixed stand of maize and blackgram (density of 1:2) within 80 cm spacing were superior to those of sole and other intercropping system at low valley situation of Kumaon hills. Kehar Singh
et al. (2000) assessed the performance of sorghum (*Sorghum bicolor* cv. CSH 9) intercropped with guar and blackgram (*Phaseolus mungo* *Vigna mungo* cv. T-9 under different planting geometries viz. sole sorghum 45 cm apart; sorghum + 2 rows of guar at paired row (PR) planting 30/90 cm apart; sorghum + guar at alternate row (AR) planting 30 cm apart; sorghum + guar at alternate row (AR) planting 30 cm apart; sorghum + 2 rows blackgram at PR 30/90 cm; and sorghum + blackgram at AR 30 cm apart and N levels (0, 60 and 120 kg ha⁻¹). All intercropping systems produced higher yields than sole cropping. Sorghum + guar intercropped in paired rows at 30 or 90 cm was the best intercropping system in terms of total productivity. Paired row planting was better than alternate rows for producing higher yields of legume intercrops.

Kulandaivel et al. (2001) determined the effect of intercropping with blackgram and onion on cotton yield and reported that the high planting density (55555 plants ha⁻¹) had higher seed cotton yield over the normal density (44444 plants ha⁻¹). Weed population comprised of grasses, sedges and broad leaved weeds were reduced under high planting density and paired row planting with blackgram as intercrop. Blackgram recorded maximum economic return compared to onion. High density cotton with blackgram as intercrop under
paired planting had the highest land equivalent ratio, income equivalent ratio and cotton equivalent ratio.

### 2.2.2 Effect on nutrient content and uptake in plant

The combined application of N and P and seed inoculation with appropriate *Rhizobium* culture increases the nutrients (Bhandari *et al.*, 1989, Bhalu *et al.*, 1995, Singh *et al.*, 1993). Application of S @ 30 kg ha\(^{-1}\) either as gypsum, pyrites or elemental sulphur resulted in significantly higher nutrient uptake in blackgram (Singh and Aggarwal, 1998). N, P, K and S uptake increased up to 100 and 75% RDF applied in rainy season (Shivram and Ahlawat, 2000b).

### 2.2.3 Effect on soil physico-chemical properties

Most of the pulse crops have deep and profuse root system and consequently they open up soil and add considerable amount of organic matter. The crop stubbles of pulses are also easily decomposed. In some of the pulses like pigeonpea, the leaf fall is tremendous which adds organic matter to the soil. Under pulse crops the soil aggregation, soil structure and the infiltration rate are considerably improved compared to the cereals. In sandy desert soils of Rajasthan, Haryana and Gujarat where most of the food crops are unproductive, mothbean grows fairly well. Similarly, on shallow *Alfisols* of peninsular India, horsegram is the most successful crop under low and erratic rainfall conditions.
Pigeonpea being a deep rooted crop performs fairly well in low rainfall areas. Pulse crops, in general improve the physical and chemical conditions of soil, reduce soil erosion, synthesise atmospheric nitrogen and enhance activities of soil fauna (Singh, 1992b). Chaudhary and Das (1996) reported that the addition of P, S and Mo application in kharif legume on eroded soil exhibited the improvement in physico-chemical properties.

2.3 Nutrient management in urdbean
2.3.1 Effect on crop productivity

The use of nitrogen in pulses promote rhizobial growth for nitrogen fixation and also to meet initial requirement of seedling. Consequently a shorter dose of 10-20 kg N ha\(^{-1}\) was recommended for pulses in general. However, the development of new genotypes suitable for different agro-climatic regions and season have brought new changes in the recommendation of fertilizer N for successful pulse production.

Rajendran et al. (1974a) have reported a significant increase in yield of urdbean with graded level of applied N (0, 30 and 60 kg N ha\(^{-1}\)). In a subsequent study, Rajendran et al. (1974b) proposed 30 kg N ha\(^{-1}\) as the optimum dose for blackgram. Namdeo and Ghatge (1976) reported that inoculation with *Rhizobium* partially met N requirement of the
crop and application of N further increased the yield by 26 per cent. Samiullah et al. (1981) reported that 20 kg N ha⁻¹ increased pod number plant⁻¹ by 12.5 per cent, pod size by 11.0 per cent, seeds pod⁻¹ by 8.0 per cent, 1000-seed weight by 5.0 per cent and seed yield by 20.5 per cent as compared with the control. Thakur and Negi (1985) found that in blackgram application of 10 and 20 kg N ha⁻¹ increased the branches plant⁻¹ over no nitrogen in 1981 and 1982, respectively. All the yield attributes (pods, grains and grain yield plant⁻¹ and 1000-grain weight) recorded significantly higher value than no nitrogen, except pods plant⁻¹ in 1982, which was not affected by nitrogen. The difference between 10 and 20 kg N ha⁻¹, were significant in pods plant⁻¹ in both the season and 1000-grain weight in 1982 only where 20 kg N ha⁻¹ had higher values of these parameter than 10 kg N ha⁻¹. They also observed that the application of 60 kg P₂O₅ ha⁻¹ resulted in significant increase in all the yield contributing characters except, number of branches plant⁻¹ and 1000-grain weight as compared to no phosphorus and 30 kg P₂O₅ ha⁻¹.

Bhalu et al. (1995) reported that seed yield of blackgram increased with up to 20 kg N ha⁻¹ (464 kg). Nitrogen requirement of pulses are substantially met through the action of Rhizobium bacteria in the nodule. The application of nitrogen as starter dose @ 15-20 kg N ha⁻¹ helped in the
establishment of the crop which ultimately led to the extensive
development of root nodule and bacteria present in them
fulfilling the need of the crop for nitrogen. Trivedi (1996)
observed that increasing levels of nitrogen significantly
increased the yield attributes and grain yield of blackgram up
to 30 kg ha\textsuperscript{-1}. Application of 15 and 30 kg ha\textsuperscript{-1} increased the
average grain yield over control by 19.2 and 40.6 per cent,
respectively. Sharma et al. (2000) noted that increasing levels
of N from 0 to 20 kg ha\textsuperscript{-1} produced significantly taller plants
as compared to 0 kg N ha\textsuperscript{-1}. Similarly, dry matter
accumulation (g plant\textsuperscript{-1}) also increased progressively till
harvest.

Crops do vary greatly in their ability to utilize
phosphorus from applied fertilizer in soil. In general, the
utilization efficiency of applied P is 5-15 per cent (Brady,
1988). In a study on the relative efficiency of mungbean,
chickpea and cowpea, it was found that P utilization by
cowpea was 2-3 fold higher than by other two crops (Sinha
and Rai, 1983). Similarly, Joshi et al. (1977) observed that
cowpea, mungbean and urdbean utilized more fertilizer P than
pigeonpea, soybean and groundnut.

Singh et al. (1986) reported that the increasing levels
of phosphorus increased the grain yield by a margin of 9.6,
37.0 and 37.3 per cent with the application of 20, 40 and
60 kg P₂O₅ ha⁻¹, respectively over control, but there was no significant difference between 40 to 60 kg P₂O₅ ha⁻¹. The increase in grain yield by the application of phosphorus may be explained on the basis of the significant improvement in number of pods plant⁻¹, number of grains pod⁻¹ and 1000-grain weight. Subbian and Ramaih (1981) also reported an increase in grain yield of pulses by the application of phosphorus. Stover yield also increased significantly to the tune of 12.2, 35.9 and 36.5 per cent by the application of 20, 40 and 60 kg P₂O₅ ha⁻¹, respectively over control. Kushwaha (1993) observed maximum yield and improved nodulation in kharif urdbean by application of 90 kg P₂O₅ ha⁻¹. The mean response of chickpea, fieldpea, urdbean, mungbean and lentil to 33.6 kg P₂O₅ ha⁻¹ was 170, 340, 15, 80 and 140 kg ha⁻¹ (Prasad, 1979).

There are a number of reports on the beneficial effect of phosphorus on the growth and yield of blackgram (Singh and Virk, 1965, Rajendran and Krishnamoorthy, 1975 and Ram and Giri, 1975). Panwar et al. (1977) reported a linear increase in the yield up to a level of 60 kg P₂O₅ ha⁻¹, above which (90 kg P₂O₅ ha⁻¹), there was a decline in the response. On an average, application of 30 and 60 kg P₂O₅ ha⁻¹ resulted a yield increase of 23 and 42 per cent. Rajendran et al. (1974a) observed a yield increase with P application of 90 kg
It was reported by these authors in their subsequent study (Rajendran et al., 1974b) found that with increased application of P, the extractable P in the soil increased up to flowering stage after which it started declining perhaps due to rapid removal by plant and its fixation in the soil. As P is essential in the mechanism of N fixation and for growth of nodule bacteria, its application to blackgram with or without inoculation has also been reported to increase N status of soil (Bahl et al., 1988). When the soil is very poor in extractable P, crop depends highly on the applied phosphatic fertilizer (Rajendran et al., 1973). A combined application of 20 kg N and 40 kg P₂O₅ ha⁻¹ could give the most economical returns to farmer (Kalsi et al., 1982).

Sharma et al. (1990) studied on rainfed blackgram by taking 2 dates of sowing and 0, 30, 60 or 90 kg P₂O₅ ha⁻¹. They indicated that the economic optimum fertilizer rates, calculated by using an equation based on the process of the fertilizer and the produce were 52.85 and 42.52 kg P₂O₅ ha⁻¹ for crops sown on 25 June and 15 July, respectively, with corresponding yield responses of 148.29 and 137.49 kg seed ha⁻¹. Rao et al. (1990) noted that increasing P₂O₅ rates up to 60 kg ha⁻¹ increased seed yield of V. mungo. Shah et al. (1994) tested 0, 30 or 60 kg P₂O₅ ha⁻¹ in blackgram and found that seed yield was highest under 30 kg P₂O₅ ha⁻¹ and it also
increased the dry matter yield. Singh and Ali (1994) reported that mungbean responded substantially to P up to 20 kg P$_2$O$_5$ ha$^{-1}$, resulting in an increase of 103 kg ha$^{-1}$. However, the yield increased with the application of 40 kg P$_2$O$_5$ ha$^{-1}$ where the soils are deficient in P. Similarly, in urdbean, discernible response accrued up to 25 kg P$_2$O$_5$ ha$^{-1}$. Mungbean responded to P application resulting in a response of 3 kg grain kg$^{-1}$ P$_2$O$_5$ in North-East plain zone and 6 kg grain kg$^{-1}$ P$_2$O$_5$ in North-West plain zone at 30 kg P$_2$O$_5$ ha$^{-1}$. The corresponding response of urdbean was 2.5 and 6 kg grain kg$^{-1}$ P$_2$O$_5$ at 20 kg P$_2$O$_5$ ha$^{-1}$ level.

Mahmud et al. (1997) observed the response of blackgram to three levels of phosphorus (0, 13 and 16 kg P ha$^{-1}$). Plant height, weight of seeds plants$^{-1}$, weight of pods plant$^{-1}$, 1000-seed weight and seed yield were significantly increased with increasing phosphorus application from 0 to 26 kg P ha$^{-1}$. Shrinivasan et al. (1997) revealed that seed yield and net return of blackgram were greatest with 60 kg P$_2$O$_5$, while, cost:benefit ratio was greatest with 49 kg P$_2$O$_5$. Ramamoorthy et al. (1997) studied in V. mungo and found that the application of P 60 kg ha$^{-1}$ significantly increased the plant height and dry weight plant$^{-1}$, but was on par with P at 40 kg ha$^{-1}$. Number of pods plant$^{-1}$, grains pod$^{-1}$, 100-grain weight and pod length were more with 40 kg P ha$^{-1}$. 
Application of P @ 40 and 60 kg ha\(^{-1}\) were significantly superior to 20 kg P ha\(^{-1}\) and the control. This was mainly due to increasing value of yield attributes particularly pods plant\(^{-1}\) and grains pod\(^{-1}\). This was in line with the findings of Salam and Nair (1982).

Potassium is rarely applied to pulse crops because of high content of K in the soils, particularly in soils, which have K bearing clay minerals like illite (Pasricha and Bahl, 1996). They also found that the application of potassium regulates the utilization of other nutrients in the plant system. N : K ratio in plants vary from 0.82 to 1.2 with an average value of 1:1 but the use of fertilizer potassium is far less than the N. George et al. (1981) recorded highest grain yield of blackgram (411 kg ha\(^{-1}\)) at 30 kg K\(_2\)O ha\(^{-1}\). Saxena et al. (1996) reported that seed yield was higher with 40 kg K\(_2\)O ha\(^{-1}\). Seed yield was positively correlated with leaf area, dry matter plant\(^{-1}\), number of branches, number of pods, seed yield plant\(^{-1}\), 1000-seed weight and harvest index of greengram. Kushwaha (2001) observed in pea that the highest seed yield was recorded with 60 kg K\(_2\)O ha\(^{-1}\) during both the years. The mean yield data indicated that the potash use efficiency was recorded to the tune of 8.70 and 18.03 kg seed kg\(^{-1}\) of K\(_2\)O for 30 and 60 kg K\(_2\)O ha\(^{-1}\), respectively over control.
In a field study at Ludhiana, Aulakh and Pasricha (1977a) reported that application of 20 kg P₂O₅ ha⁻¹ as single super phosphate (which contains about 12.5 % S) gave an extra yield of 1.1 and 1.59 q ha⁻¹ over the same rate of P applied as diammonium phosphate and triple super phosphate. Lal and Jaiswal (1979) reported 23 per cent increase in grain yield with the application of 30 kg S ha⁻¹ as gypsum on an alluvial soil having 8 mg kg⁻¹ of soil as available S. In a green house study, an increase of 15 per cent in the dry matter production with 25 kg S kg⁻¹ was observed (Tandon, 1984).

Tiwari and Chaplot (1995) observed that seed yield of mungbean increased significantly with an increase in sulphur rate up to 100 kg ha⁻¹. Ravichandran et al. (1995) studied that when blackgram applied at 0, 20 or 40 kg S ha⁻¹ as single super phosphate, pyrite or gypsum resulted in highest seed yield with 40 kg S ha⁻¹ as single super phosphate (0.63 t ha⁻¹). Ghosh et al. (1996) revealed that application of 20 kg S ha⁻¹ as gypsum to blackgram and greengram recorded the highest seed yield (1.43 t ha⁻¹). The highest seed yield was recorded with fertilizer placement (1.26 t ha⁻¹) over broadcasting (1.16 t ha⁻¹).

Ramamoorthy et al. (1997) observed in blackgram that sulphur application @ 40 kg ha⁻¹ resulted in increased
growth in terms of plant height and plant dry weight and yield attributing characters viz., pods plant$^{-1}$, grains pod$^{-1}$ and 100-grain weight and grain yield of blackgram under rainfed condition than 20 kg S ha$^{-1}$. Sharma and Singh (1997) reported in greengram that the S application significantly increased the plant height and branches plant$^{-1}$ up to 40 kg ha$^{-1}$. Sulphur application also increased pods plant$^{-1}$ and grains pod$^{-1}$ up to 60 kg ha$^{-1}$. However, maximum test weight and straw yield was noted in 40 kg S ha$^{-1}$ over the control. Since, the yield obtained at 40 and 60 kg S ha$^{-1}$ were at par and hence dressing of S at 40 kg S ha$^{-1}$ is better to the later.

2.3.2 Effect on nutrient content and uptake in plant

Adequate application of P (40 kg P$_2$O$_5$ ha$^{-1}$) not only increased yield but also helped in increasing root nodulation and consequently N content of grains (Sahu, 1973, Kadwe and Bhade, 1973 and Namdeo and Ghatge, 1976). Increasing P rates increased the plant P and K contents, increase in N content was not significant. Kamath et al. (1981) reported that the uptake of S is greatly influenced by S application, which improved the quality parameters of the crop.

Khandkar and Shinde (1991) tested 0, 30 or 60 kg P$_2$O$_5$ ha$^{-1}$ in V. mungo and noted that seed P content and uptake increased up to 60 kg P$_2$O$_5$. Phosphorus content and uptake in seeds were highest with 60 kg P$_2$O$_5$ ha$^{-1}$. Bansal
(1991) studied on soybean, *V. radiata* and *V. mungo* with 0, 20, 40 or 80 kg S ha\(^{-1}\). The seed yields and N, P, K and S content and uptake in all crops increased with rate of S application. Singh and Tripathi (1992) reported that nitrogen uptake increased significantly with P application (0, 20, 40 and 60 kg P\(_2\)O\(_5\) ha\(^{-1}\)). Singh *et al.* (1993) observed that uptake of N in blackgram increased with fertilizer application. Bhalu *et al.* (1995) reported that nitrogen and phosphorus uptake and seed protein content increased with increasing N rates (10, 20 and 30 kg N ha\(^{-1}\)).

Singh and Aggarwal (1998) reported that application of 30 kg S ha\(^{-1}\) also increased N, P and S uptake by seed. Singh *et al.* (1998) observed in chickpea that protein content significantly increased at 20 kg S ha\(^{-1}\). Shankaralingappa *et al.* (1999) revealed that when pigeonpea were given 0, 50 or 75 kg P ha\(^{-1}\), the protein content of seeds was increased by P application, while, protein yield and methionine content increased with increasing P rates, with 50 kg P giving the best results.

### 2.3.3 Effect on soil physico-chemical properties

Chaudhary and Das (1996) found that the application of P, S and Mo application in *kharif* legume on eroded soil exhibited the improvement in physico-chemical properties. Rao and Singh (1991) found that inclusion of greengram in
cropping sequence increased the available nitrogen status significantly.

The organic carbon, soil available N, P and K content was found higher or showed positive build up with blackgram-wheat cropping system after three years experimentation. The application of higher level of P (17.24 kg ha\textsuperscript{-1}) also increased the soil nutrient status of soil with higher values of organic carbon and soil available N, P and K. Blackgram-wheat cropping sequence maintains sustainable level of soil fertility without impairing any adverse effect on soil and their productivity (Shrivastava et al., 2003).

2.4 Direct and residual effect of nutrient on wheat

2.4.1 Direct effect of nutrient

According to Singh et al. (1982) nitrogen application up to 80 kg have significantly affected the plant height of wheat. Rana et al. (1982) reported that application 60 and 120 kg N ha\textsuperscript{-1} produced an increase yield of 8.72 and 13.72 q ha\textsuperscript{-1} over no nitrogen, respectively. Addition of 30 and 60 kg P\textsubscript{2}O\textsubscript{5} ha\textsuperscript{-1} to 60 and 120 kg N ha\textsuperscript{-1} produced 7.35 and 10.14 q ha\textsuperscript{-1} higher grain yield respectively over the N levels alone. Singh and Singh (1984) observed that the application of 60 kg N alongwith 120 kg seed rate ha\textsuperscript{-1} produced the maximum grain yield, which was significantly superior over other levels of nitrogen fertilizer. Singh et al. (1987) reported that increasing
nitrogen rate from 0 to 120 kg ha\(^{-1}\) significantly increased the yield component \textit{viz.} tillers m\(^{-2}\), ear length, grains ear\(^{-1}\) and dry matter accumulation plant\(^{-1}\). Duhan \textit{et al.} (1988) concluded that increasing levels of N from 80 to 120 kg ha\(^{-1}\) increased the grain yield of wheat.

Singh and Singh (1991) reported that increasing N fertilizer application from 0 to 120 kg N ha\(^{-1}\) increased the grain yield progressively. Lathwal \textit{et al.} (1992) reported that application of 0, 40, 80, 120 and 160 kg N ha\(^{-1}\) produced yield of 2.81, 3.99, 4.89, 5.48 and 5.51 t ha\(^{-1}\), respectively. Awasthi \textit{et al.} (1993) from Kanpur reported that application of N @ 60 kg ha\(^{-1}\) resulted in maximum root expansion of wheat as compared to 0, 20 and 40 kg N ha\(^{-1}\).

Mishra \textit{et al.} (1994) reported that grain yield increased with increasing N, and was highest with 90 kg N ha\(^{-1}\). Nayak \textit{et al.} (1997) reported that by application of N (0, 50, 120 and 180 kg ha\(^{-1}\)), grain and straw yields increased significantly only up to 120 kg N ha\(^{-1}\). Oscarson \textit{et al.} (1995) reported that application of N increased shoot and grain dry matter production only. The extra nitrate applications had significant effects on grain nitrogen content at all stages. Shrivastava \textit{et al.} (1995) reported that application of 120 kg N ha\(^{-1}\) delayed the maturity and increased the number of effective ear's alongwith grain and straw yield over 60 kg N.
ha\(^{-1}\), but variation in grain yield was not significant. Kumar et al. (1995) reported that protein content increased by 30% under 120 kg N ha\(^{-1}\) as compared to control. Lee et al. (1995) indicated that nitrogen applied at different growth stages improved the protein content in grain.

Banga et al. (1996) reported that N content in grain and straw was improved with the addition of nitrogen. However, N uptake both in grain and straw was increased significantly only up to 120 kg N ha\(^{-1}\). Singh et al. (1996) reported that N uptake increased with N application. Singh (1997) reported that the effect of nitrogen in fertilized plot (40 and 80 kg N ha\(^{-1}\)) was 11.7% higher than the unfertilized plot (no nitrogen). Increase in dry weight was observed with the increase in N level.

2.4.2 Residual effect of nutrient

Singh and Singh (1984) observed that the use of soybean and blackgram (Vigna mungo) as intercrops in maize in the monsoon season increased the maize grain yield by 17-22% and also increased the grain yield of the succeeding wheat crop in the winter season by 15-20% compared with wheat sown after maize in pure stands. Mahadkar and Saraf (1988a) reported that the inoculation, pre-sowing application of 40 kg \(\text{P}_2\text{O}_5\) or 20 kg N ha\(^{-1}\) at the pre-flowering stage increased the seed yields of urdbean by 15.9, 40.7 and 13.9%,
respectively compared with respective untreated controls. The
treatment showed residual effect on fresh fodder and dry
matter yields of the subsequent sorghum crop. P showed the
highest residual effect. Mahadkar and Saraf (1988b) studied
the effect of *Rhizobium* inoculation and P and N application on
growth and yield of *V. mungo* and its residual effect on fodder
sorghum. In a 2 years field experiment they found that
fertilizer application of 16 kg P ha\(^{-1}\), 20 kg N ha\(^{-1}\) as a starter
application or 20 kg N ha\(^{-1}\) as top dressing at the pre-
flowering stage, significantly increased DM and seed yields
over their control. The number of dry weight of nodules was
significantly increased by inoculation followed by P and starter
N application, but significantly reduced by N top dressing. Dry
matter yield of the following sorghum crop was significantly
increased by all treatments.

Thakur (1995) studied on maize *cv. L-19* grown alone
in the *kharif* or intercropped with blackgram *cv. PDU-1*
followed by wheat *cv. DH-2380* in the *rabi*. Both maize and
wheat were given 0-90 kg N ha\(^{-1}\). The maize grain equivalent
yield was higher when intercropped with horsegram than with
blackgram or when grown alone. Maize grain equivalent yield
increased with rate of N application applied directly or
through residual effects on N applied to wheat. Wheat grain
yield was higher when grown after maize + legumes than after
maize grown alone. Wheat yield increased with increase in N applied to wheat or the previous maize crop. The highest net returns were obtained from growing the maize + horsegram wheat sequence. Singh et al. (1995) studied on maize and blackgram (Vigna mungo) grown alone or intercropped with their individual fertilizer. The rates applied separately to each crop or mixed and applied uniformly to both crops. Blackgram was sown at 50, 75 or 100% of its recommended seeding rate (20 kg seed ha⁻¹) and given 50, 75 or 100% of its recommended fertilizer rates of 20 kg N + 11.7 kg P ha⁻¹. Soil available N was decreased by sole maize in the first year but was replenished in the second year. Sole blackgram enriched soil N. Enrichment of soil N in intercropping treatments was dependant on blackgram population and fertilizer levels and was highest in the first and second year with 100% population and 75% fertilizer, respectively. The grain yield of wheat following maize + blackgram intercrops with 100% of blackgram fertilizer and population was 8.5% higher than that following sole maize.

Patra (2001) conducted 3 years experimentation to determine the effect of P at 0, 50 and 100 kg ha⁻¹ on several legumes and the residual effect of P on the productivity and N economy of the succeeding crop (wheat cv. Sonalika) N at 0, 60 and 120 kg ha⁻¹ was also applied to winter wheat. The
legumes in the study comprised of soybean (*Glycine max* *cv* bragg), greengram WB 105, blackgram (*cv.* T-9), and rice bean (*cv.* K 1). P at 50 kg ha⁻¹ produced the highest legume seed or fodder yields. Soybean had the highest among the legumes and was the most efficient in terms of residual effect on the succeeding wheat crop. Wheat yield was highest when the previous crop was soybean. Grain yield of wheat increased with increased levels of P applied in the previous crop, and with increasing N, rates. The direct effect of P on the legumes was positive up to 50 kg ha⁻¹. Results indicated that N level on wheat could be reduced to 60 kg ha⁻¹ when wheat was grown after legumes, particularly soybean.

Shivram and Ahlawat (2000b) reported that the highest mean net returns was obtained from pigeonpea or blackgram-wheat cropping system, where rainy-season crop and wheat were applied with 100% and 75% of the rec. dose of fertilizer, respectively. Ahmad *et al.* (2001) from Pakistan reported that crop legumes, grown in rotation with cereal crops, contributes to the pool of nitrogen in the soil and improve the yield of cereals. N fixed ranged from 26 to 36 kg ha⁻¹ where rice followed the mungbean and blackgram and from 30 to 36 kg ha⁻¹ where wheat followed the mungbean and blackgram. Soil nitrogen spared by legume crops ranged from 2 to 26 kg ha⁻¹ in rice-mungbean/blackgram rotation and from
4 to 23 kg ha\(^{-1}\) in wheat-blackgram/mungbean rotation. Rice paddy yield were 0.6–1.1 t ha\(^{-1}\) higher in the legume-cereal rotation than in the cereal-cereal sequence. Similarly, wheat grain yield were 0.5–1.1 t ha\(^{-1}\) higher in the legume-cereal rotation.

### 2.5 Energy studies

Singh et al. (1981) studied the energy requirement of paddy, cotton, maize and wheat and reported that all the crops consumed majority of energy from mechanical sources. Singh et al. (1997) concluded that energy requirement of chickpea production in Madhya Pradesh was 2336 and 5237 MJ ha\(^{-1}\) operation-wise and source-wise, respectively. Energy ratio was found 8.60 and specific energy was 4.76 MJ kg\(^{-1}\). Sharma et al. (1998) from Sehore, concluded that the total production energy requirement for chickpea (Cicer arietinum L.) production was estimated to be 3534 MJ ha\(^{-1}\), of which their operational energy was 1204 MJ ha\(^{-1}\). The input energy ratio was 6.65.

Guruswomy et al. (2001) while studying on energy requirements for crop production under dry land agriculture found that redgram consumed maximum human and animal energy. The energy consumption were the highest for harvesting, tillage operation and sowing operations, whereas, the energy output through by product was more than the main
product. The energy requirement for primary and secondary tillage operation was 444 MJ ha\(^{-1}\) and 125 MJ ha\(^{-1}\) for redgram. The operation-wise energy consumption was 1167 MJ ha\(^{-1}\) for redgram and 1176 MJ ha\(^{-1}\) for greengram crop. The output energy of redgram from main and by products were 6321 MJ ha\(^{-1}\) and 23320 MJ ha\(^{-1}\), respectively. The energy ratio of redgram and greengram was 4.37 and 4.20 for the main product, but for the by products it was 16.08 and 12.88, respectively. The total output-input energy ratio was 20.45 for redgram followed by greengram, sorghum and sunflower.

### 2.6 Economics

Sharma et al. (1990) studied in blackgram sown on 2 dates and given 0, 30, 60 or 90 kg P\(_2\)O\(_5\) ha\(^{-1}\). The economic optimum fertilizer rates calculated by using an equation based on the price of the fertilizer and the produce were 52.85 and 42.52 kg P\(_2\)O\(_5\) ha\(^{-1}\) for crops sown on 25 June and 15 July, respectively. Singh et al. (1993) studied the greengram and blackgram under no fertilizers, 20 kg N, 20 kg N + 40 kg P\(_2\)O\(_5\) or 20 kg N + 40 kg P\(_2\)O\(_5\) + 40 kg K\(_2\)O ha\(^{-1}\) with or without seed inoculation with *Rhizobium*. They found that the net economic return was higher in blackgram. Inoculation increased the economic return. Shrinivasan *et al.* (1997) studied on blackgram with 0, 20, 40 or 60 kg P\(_2\)O\(_5\) ha\(^{-1}\) and 0, 20 or 40 kg S ha\(^{-1}\). The net return was greatest with 60 kg P + 40 kg S,
while benefit cost ratio was greatest with 40 kg P + 40 kg S. Vairavan et al. (1997) noted the high benefit cost ratio of 1:1:29 by application of ZnSO₄ @ 25 kg ha⁻¹ in blackgram than any other treatment combination.

Shrinivasan et al. (2000) reported in blackgram that the source and level of sulphur were found to alter the benefit cost ratio (BCR). Sulphur nutrition through gypsum was more effective in increasing the monetary returns. Gypsum gave the highest BCR of 3.33 and 2.43 during kharif and rabi season, respectively. Among the levels, 40 kg S ha⁻¹ produced the highest BCR, which was comparable with the BCR produced by 30 kg S ha⁻¹.

Working on wheat, Rana et al. (1982) and Rathore and Patel (1991) reported that the net return was the highest with 120 kg N ha⁻¹. Singh and Uttam (1993) from Kanpur reported that in wheat nitrogen level of 60 kg N ha⁻¹ gave maximum net return and net return rupee⁻¹ spent. Rajput (1995) reported that in wheat application of 120 kg N ha⁻¹ as foliar in 3 equal splits was superior in terms of benefit cost ratio in comparison to 40 kg N ha⁻¹ as basal + 80 kg N ha⁻¹ as foliar in 3 splits.