SUMMARY
The present investigation entitled “Studies on neem based agroforestry systems in Bundelkhand region” was carried out in the Research Farm of National Research Centre for Agroforestry (NRCAF), Jhansi (Uttar Pradesh) during two consecutive years viz. January 1998 - March 2000.

The experiment was conducted in 8-year and 4-year-old neem plantations at two separate sites. To make six replications, fifty four trees (each replication had trees in 3x3 orientation) were selected at each site. The tree growth data were recorded on collar diameter (cd), diameter at breast height (dbh), tree height and crown diameter in each replication at each site at quarterly interval. Phenological observations and litter fall in trees were recorded at 15 days interval.

Studies on tree-crop interface effects on the understorey crops were executed in both the age groups of neem plantations in the cropping season. At site I, Urd (Phaseolus mungo) var. NDU-1 was sown as understorey crop under 8-year-old plantation as well as in adjacent open area (crop without trees as control) in Kharif season and at site II, gram (Cicer arietinum) was sown as understorey crop under 4-year-old plantation as well as in adjacent open area in Rabi season. The observations were recorded on vegetative and grain yield components of understorey crops, availability of soil moisture and photosynthetically active radiation (PAR) and status of leaf temperature of understorey crops. These parameters were recorded at four distances (50, 100, 150, 200 cm) in west and east direction from center line of the trees which was in north to south direction in each replication under the tree canopy and in open area (without trees).

To find out the effect of trees on soil properties, the soil samples were collected before the start of experiment and after termination (after 2 years) at both sites in all
six replications at 4 distances (50,100,150, and 200 cm) from center line of the trees in west and east direction. The soil chemical properties were analyzed for soil pH, organic carbon, available nitrogen, available phosphorus and available potash.

A salient findings of the study pertaining to growth pattern of neem, its phenology, litter fall and nutrient return from litter fall, tree-crop interface and effect of neem trees on status of soil properties are presented below:

Growth of neem trees in Bundelkhand region is throughout the year with maximum growth in rainy season (July-September) for all growth parameters i.e. collar diameter, diameter at breast height, tree height and crown diameter.

Trees attained height of 435.33 cm (MAI 108.83 cm), 489.98 cm (MAI 98 cm) and 545.70 cm (MAI 90.95 cm) at 4th, 5th and 6th year of growth, respectively. Tree height was 615.38 cm (MAI 76.92 cm), 680.04 cm (MAI 75.56 cm) and 745.45 cm (MAI 74.55 cm) at 8th, 9th and 10th year of growth, respectively.

The collar diameter and diameter at breast height are 9.21 and 6.40 cm (MAI 2.30 and 1.6 cm); 11.36 cm and 8.19 cm (MAI 2.27 and 1.64 cm); 14.25 cm and 10.50 cm (MAI 2.38 and 1.75 cm) at 4th, 5th and 6th year of neem tree growth, respectively. The same was 13.37 cm and 10.48 cm (MAI 1.67 and 1.31 cm), 15.55 cm and 12.32 cm (MAI 1.73 and 1.37 cm); 17.51 cm and 14.0 cm (MAI 1.75 and 1.4 cm) at 8th, 9th and 10th year of neem tree growth, respectively in this region.

The crown diameter of neem trees was 214.26 cm (MAI 53.57 cm); 276.18 cm (MAI 55.24 cm) and 331.70 cm (MAI 55.28 cm), 382.46 cm (MAI 47.81 cm), 430.17 cm (MAI 47.80 cm) and 472.43 cm (MAI 47.24 cm) at 4th, 5th, 6th, 8th, 9th and 10th year of growth, respectively.

The peak litter fall period of neem trees in Bundelkhand region was in second
fortnight of February to end of March in which maximum contribution was of leaves. During this period, under the tree cover the area is full of leaf litter. Annual litter production was 2976 kg/ha in 4-year-old plantation (625 tree/ha) and 6059 kg/ha in 8-year-old plantation (500 tree/ha). Trees bear new lush green leaves up to second week of April. The peak flowering season of neem trees in Bundelkhand region is from April 15th to May 15th and fruiting closes up to last week of May. The time of collection of seeds in this area is from 20th June to 15th of July.

The chemical composition (N, P, K and Ca) and quantity of neem litter fluctuates seasonally. In the period of leaf fall in February and March, nitrogen content in litter was lower while phosphorus, potassium and calcium were higher while in April, nitrogen content of litter was higher and phosphorus content was lower.

The nutrient return through litter was 50.05 kg/ha for nitrogen, 1.105 kg/ha for phosphorus, 13.18 kg/ha for potassium and 58.33 kg/ha for calcium under 4-year-old plantation. The return of nutrients through litter under 8-year-old plantation was 98.02 kg/ha for nitrogen, 2.245 kg/ha for phosphorus, 32.02 kg/ha for potassium and 131.30 kg/ha for calcium.

The light interception by neem trees in 4-year and 8-year age was recorded. The reduction of photosynthetically active radiation (PAR) under tree canopy was 28-40% in 5th year, 44-54% in 6th year in 4-year-old neem plantation, 56-68% in 9th year and 79-87% in 10th year in 8-year-old neem plantation. The lowest value of PAR was near to tree base (50 cm) and it increased with increasing distances from tree base. The leaf temperature of Urd and gram under the tree canopy was reduced by 0.88-1.20°C and 0.84-1.27°C as compared to open area.

In general, moisture availability under the tree canopy was lower as compared to open area (control). The lowest moisture content in soil was recorded near the tree base (50 cm). In Kharif season moisture reduction under tree canopy was 12.59 to
15.18% in 1998 and 0.56 to 6.31% in 1999, respectively. During Rabi season, soil moisture was reduced by 9.2 to 20.51% under trees canopy in 1998 but higher by 8.80 to 18.67% in 1999 under 4-year-old-neem plantation.

Vegetative growth and yield of gram was depressed under canopy of neem of 4-year of age. On the basis of mean of two years of investigation, the reductions were 13.30% for height, 37.20% for plant density, 34.35% for number of primary branches and 25.05% for number of pods per plant as compared to open area (control). Weight of 100-seed was slightly higher under tree canopy as compared to open area. The reduction in grain yield of gram per meter row under tree canopy was 40.50% up to 50 cm, 37.60% up to 100 cm, 32.64% up to 150 cm and 28.33% up to 200 cm distance from tree base as compared to open. The yield of under storey crop was decreased with increasing age of neem trees and lowest yield of crop was recorded near tree base (50 cm).

Urd was sown under canopy of 8-year-old plantation of neem during Kharif season. Vegetative growth of Urd was significantly lower under tree canopy. On an average of two years, plant density, stem girth, plant height, number of leaves per plant and number of branches of Urd were reduced by 42.68%, 35.00%, 31.66%, 31.92% and 52.59%, respectively under tree canopy as compared to open area. On an average of two years, yield per plant was reduced by 75.70%, length of pod per plant by 10.82%, number of grains per pod by 15.84% and 100-seed weight by 8.91% under tree canopy as compared to open. The yield of Urd per meter row under tree canopy decreased by 78.79% up to 50 cm, 74.76% up to 100 cm, 72.71% up to 150 cm and 69.29% up to 200 cm as compared to open. The reduction was maximum near the tree base and increased with increasing distances from tree base. The reduction in yield of under storey crop was increased with increasing age of trees.

The findings of present investigation showed that the pH of the soil decreased in both the plantations over the open area (control). Soil under the trees contains
higher level of organic carbon compared to soil sampled in nearby open field. An increase of 0.12 and 0.11 (percentage increase was 26 and 22, respectively) in organic carbon was recorded under canopy of 8-and 4-year age of plantations, respectively.

The available nutrients (N, P and K) were higher under tree canopy as compared to open. Nitrogen content in soil increased by 37.6 kg/ha and 19.41 kg/ha over the initial values (before 2 years) in 0-15 cm soil depth under trees canopy of 8- and 4-year of neem plantations, respectively. Phosphorus and potassium are increased by 2.41 kg/ha, 51.01 kg/ha and 2.32 kg/ha, 43.82 kg/ha under 4-and 8-year-old plantation of neem, respectively. Nitrogen, phosphorus and potassium content in soil decreased with profile depth in both the plantations.

The relative advantage of neem based agroforestry system over sole cropping was estimated. In first agroforestry model (8-year-old neem plantation + Urd), the relative advantage of model over sole cropping of Urd was Rs.21,010/ha in 1998 and Rs.31,048/ha in 1999. In second model (4-year-old plantation of neem + gram), the relative advantage of model over sole cropping of gram was Rs.10,260/ha in 1998 and Rs.10,670/ha in 1999. Besides economic benefits and employment generation, neem trees maintain soil fertility, control soil degradation and decrease air pollution and raising of atmospheric temperature.
Recommendations and Conclusions

Neem tree grows throughout the year but maximum growth take place in the period of July to September (rainy season).

The maximum litter fall takes place in the month of February and March. The leaf contributes major portion (98%) of litter.

Neem trees bear lush green leaves in summer and its leaf is a good source of green fodder in summer when there is acute shortage of green fodder.

The period of seed collection of neem trees in Bundelkhand region is from June 20 to July 15.

Since neem tree plantation is a long gestation project, no income can be expected during the initial period of 4 to 5-year until tree starts yielding fruits. Therefore, in order to augment income during the initial years, food crops like black gram and gram can be grown successfully.

Neem based agroforestry system is profitable over sole cropping of crops in Bundelkhand region.

It is important in future plantations to consider the crown development for this species in order to choose optimal spacing and thinning regime.

To reduce shading effect of neem trees on understorey crops, pruning management and planting distance of at least 10x10 m should be maintained.

To avoid soil degradation, maintain soil fertility and to generate income and employment opportunities, neem based agroforestry system is suitable for Bundelkhand region.