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Original article

Effect of different intercropping systems on soil moisture conservation, fruit yield and quality of Nagpur mandarin (*Citrus reticulata*) in central India

P.S. Shirgure*
National Research Centre for Citrus, Nagpur, Maharashtra 440 010.

*Corresponding author; National Research Centre for Citrus, Nagpur, Maharashtra 440 010, India.

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ABSTRACT

A field experiment was conducted during 2009-2012 to study the integrated field crop based intercropping systems with cotton as main and other field crops (black gram, soyabean, groundnut, gram and mungbean) as intermediate intercrops in pre-bearing as well as bearing Nagpur mandarin orchards. The treatment consisted of Nagpur mandarin + cotton, Nagpur mandarin + cotton + soyabean, Nagpur mandarin + cotton + blackgram, Nagpur mandarin + cotton + groundnut, Nagpur mandarin + soyabean followed by gram, Nagpur + black gram followed by gram, Nagpur mandarin + groundnut followed by summer mung and with no intercrop. The plant canopy volume of Nagpur mandarin shown maximum increase of 28.81 m^3 in Nagpur mandarin + soyabean followed by gram. The highest Nagpur mandarin yield 20.0 t/ha (72.3 kg/tree) was recorded in the intercropping of Nagpur mandarin + soyabean followed by gram. The pre-bearing orchard the Nagpur mandarin + black gram followed by gram was shown significant increase (10.66m^3) followed by Nagpur mandarin + cotton + soyabean. The total soluble solids (TSS) to acidity ratio was more in Nagpur mandarin + black gram followed by gram (15.95) and Nagpur mandarin + cotton + groundnut (14.51). The fruit acidity and juice percent were also significantly affected. High soil moisture was observed in intercrops of soyabean and groundnut. The maximum cotton yield was under treatment of intercropping soyabean, black gram and groundnut compared to cotton alone. The number of pods per plants was more in soyabean grown with cotton (92.6) as compared to soyabean alone. This study

reveled that the intercropping system with cotton + soyabean or cotton + black gram in the interspaces of pre-bearing and bearing mandarin improved the yield as well as sustainability of mandarin as well as the production of intercrops.

1. Introduction

Citrus is grown in 9.23 lakh ha area with a production of 8.6 lakh tones per annum. The important commercial cultivars of citrus grown in India are mandarin (*Citrus reticulata* Blanco) followed by sweet orange (*Citrus sinensis* Osbeck) and acid lime (*Citrus aurantifolia* Swingle) with a total production of 16.34, 35.67 and 25.71 lakh tonnes, respectively. Nagpur mandarin *(Citrus reticulata* Blanco*)* is an important commercial citrus fruit grown in *Vidarbha* region of Maharashtra (Singh, 1999). In majority of commercially grown citrus areas, citrus is usually cultivated as monoculture and any onset of epidemic to this crop may lead to crop destruction. In these major citrus grown areas, cotton is one of the commercial crops grown on wider scale besides the pulse and oilseed crops (Singh and Bakshi 1961; Chadda *et al.,* 1969 and Chundawat, 1993). The intercropping in horticulture crops like citrus is also reported by Krishnamurti (1959) and Gill (1999). The investigations of intercropping in Nagpur mandarin orchards with single inter strip crops studies are also carried out (Gonge *et al.,* 1997; Paslawar *et al,* 1999; and Huchche *et al.,* 2006). The integrated citrus based cropping system is aimed at optimised use of land, maximum return per unit area and time, soil conservation and fertility build-up, waste recycling and insurance against failure of individual crop in addition to providing year round employment and reducing the total cost of production. The declining of the citrus orchards is a major problem in India due to lack of disease free planting material, poor soil-water as well as heath management (Chadda *et al.,* 1970; Randhawa *et al.,* 1996), lack of irrigation water resources and conventional irrigation practices. The Nagpur mandarin orchards are declining due to shortage of irrigation water during the critical growth of the plants and poor drainage system in rainy season (Shirgure *et al.,* 2000). The use of different intercrops provides an effective strategy to obtain additional income during off-season without inducing any stress on soil moisture and soil fertility. The management of cotton and strip cropping with pulse and cotton based pre-bearing citrus orchards is highly remunerative per unit area in irrigated agro ecosystem both qualitatively and quantitatively. Particularly during the pre-bearing Nagpur mandarin orchard establishment more space in between the rows can be effectively utilized for intercrops. This helps citrus growers economically as the fruit bearing of the mandarin starts from fourth year onwards (Shivankar *et al,* 2004). The innovative intercropping system in Nagpur mandarin grove having cotton as main intercrop and the leguminous as well as oilseed crops like soyabean, groundnut and gram as a sub-intercrops between the cotton and mandarin is not studied under any central Indian conditions.

The main objective of this investigation is to search for suitable intercropping system consisting of central cotton crop and leguminous crops near the mandarin root zone area to improve the soil moisture and soil fertility status in long term with emphasis on the health and yield performance of citrus trees with regard to plant growth, yield, quality, nutrient and moisture conservation of main and intercrops. This aims to study the relationship and interactions between Nagpur mandarin crop and intercrops such as cotton, soyabean, blackgram, groundnut, gram and mung, which may be complementary, competitive and supplementary in addition to generate income.

2. Materials and methods

An intercropping experiment was carried out with seven intercrops on pre-bearing and bearing Nagpur mandarin during 2009-2012 at farmer's field at *Sawandri* and *Brhamni* villages in *Kalmeshwar* Tehsil of Nagpur district. The various intercropping treatments were, Nagpur mandarin + no intercrop (T_1); Nagpur mandarin + cotton (T_2); Nagpur mandarin + Cotton + Soyabean (T_3); Nagpur mandarin + Cotton + Black gram (T_4); Nagpur mandarin + Cotton + Ground nut (T_5); Nagpur mandarin + Soyabean followed by gram (T_6); Nagpur mandarin + Black gram followed by gram (T_7) and Nagpur mandarin + Groundnut followed by summer mung (T_8). The experiment was in randomized block design with three replications and six plants per unit. The soil was moderately

deep (49 cm), well drained, calcareous, clayey, gently sloping with land capability and irrigability class of IIIes. The soil moisture constants for field capacity and permanent wilting point were analysed using pressure plate apparatus (Soil moisture Inc., Santa Barbara, USA) and bulk density of the soil was estimated with core method. The pre-bearing and bearing mandarin plants were spaced at 6 m with an average canopy area of 10.75 - 13.85 m^2.

In pre-bearing stages the cotton was sown in 5 m space in between two rows of mandarin trees spaced at 6 m and in bearing orchards 3 m inter space was used for intercropping. Cotton + other intercrops: in central 3 m space was cotton and one meter each side was soybean / blackgram / groundnut. In other than cotton treatment, the intercrop was sown in 5 m space in between 2 rows of main crop in *kharif* and then followed with *rabi* crop such as gram / summer moong in the residual moisture with light irrigation if required. In bearing stages light to medium pruning of the main crop was done. In bearing mandarin orchard cotton was sown in 3 m space in between two rows of mandarin spaced at 6 m. Cotton with other intercrops was sown in 3 m space in which central 1 m was cotton and on both sides one meter was soybean / blackgram / groundnut. In treatment without cotton crop the intercrop was sown in 3 m space in between the tree rows in *kharif* and then followed with *rabi* crop. In *kharif* season cotton (*LRK-516*), soybean (*JS-335*), blackgram (*TAU-1*) and groundnut (*JL-24*) were sown as intercrops, where as in *rabi* season gram (*Chaffa*) and in summer mung (*K-581*) was intercropped. After sufficient monsoon land attained field capacity (1/3 bar soil moisture) condition the intercrops of *kharif* season were sown. The soil moisture at field capacity was 31.4 % in pre-bearing and 29.8 %, available soil depth 102 cm and 78 cm and bulk density of the soil 1.35 g/cc and 1.54 g/cc in pre-bearing and bearing Nagpur mandarin orchards, respectively. From June to September sufficient soil moisture in the main as well as intercrops was maintained due to effective rainfall. From the month of October to May, conventional gravity method of irrigation was given. Surface flooding was done in intercrops and basin method of irrigation was followed adopting the calendar method of irrigation scheduling. Irrigation was followed when 50% of available water content was depleted. The soil moisture monitoring at 30 cm depth was done at 15 days interval with the help of soil moisture monitoring soil profile probe (Profile Probe PR1, Delta T, UK) and soil moisture monitoring meter (HH2 Delta T, UK) procured under the NATP project. The FRP tubes were installed in each treatment for monitoring the soil moisture with profile probe.

The experiment was initiated and initial growth parameters were recorded during October 2000 subsequently. Increase in vegetative growth parameters, i. e plant height, stock and scion girth and canopy volume, were recorded in October 2001 and 2002. The stock girth was taken 15 cm and scion girth at 25 cm above the ground surface. The canopy volume of the mandarin tree was calculated using spread and canopy height using Castle's formula. The total fruits harvested from each tree were weighed for computing the yield. A total of 50 fruits per treatment were randomly taken for quality analysis. The total soluble solids (TSS) were determined using hand refractometer (0-32 ^{o} Brix). Titratable acidity was determined by titrating the juice against 0.1N NaOH. Percent juice content was determined by extracting the fresh juice and weighing.

3. Results and discussion

3.1. Soil moisture in Nagpur mandarin and intercropping systems

The soil moisture status in Nagpur mandarin with cotton as an intercrop was lower among the other intercropping systems. This is due to higher soil extraction by the cotton crop. This may be due to lower row spacing and larger foliage coverage. This also indicated that cotton crop required more moisture as compared to soybean, blackgram and groundnut intercrops. Comparatively higher soil moisture was observed in soybean and groundnut intercrop. Moderately high soil moisture content was recorded in *rabi* season in which soybean followed by gram, and groundnut followed by mung bean intercrops were taken. Lower soil moisture was observed during April-May months and it was due to high temperature and evaporation during summer months. The advantage of conserved soil moisture was more in pre-bearing Nagpur mandarin orchard than bearing one. The various intercrops proved to be best for utilization of the soil moisture available during the rainy season and due to irrigation also (Table 1).

Increase in soil moisture content during April-May months of summer was found significant. Higher soil moisture content was observed in treatment having Nagpur mandarin with soyabean (34.1 % and 22.6 %) at 30 cm depth during 2001-2002 and was (22.6% and 28.7 %) at 30 cm depth during 2010-2012 (Table.1). Amongst the intercrops the soyabean, blackgram and groundnut has showed significantly higher increase in soil moisture at 30 cm during both the years. This confirms with the results in intercropping in young citrus orchards (Chadha *et al.,*

1969). The higher soil moisture content below the crop canopy of the intercropping treatments might be due to reduction in soil surface evaporation and weed intensity. The Nagpur mandarin with cotton also conserved the soil moisture in the tree rootzone in comparison to Nagpur mandarin alone.

Table 1
Soil moisture status under different intercropping systems in Nagpur mandarin during 2010-2012

Treatments	Soil moisture at 30 cm depth, % (w. b)							
	2010 – 2011				2011 - 2012			
	Jun – Sept	Oct – Dec	Jan – Mar	April – May	Jun – Sep	Oct – Sept	Jan – March	April – May
	Pre-bearing Nagpur mandarin orchard							
T_1	25.49	25.12	31.87	28.99	26.44	21.12	23.38	23.58
T_2	21.81	28.87	30.82	27.50	25.87	16.13	24.42	11.05
T_3	19.40	29.74	31.23	28.89	27.41	24.82	22.80	18.65
T_4	25.82	29.93	33.38	26.11	25.34	18.43	22.70	13.94
T_5	27.59	27.08	32.21	28.75	25.34	18.09	24.10	22.62
T_6	30.65	28.82	31.72	34.19	27.40	19.69	23.18	22.67
T_7	25.44	29.90	32.19	29.87	30.53	22.46	22.05	22.85
T_8	28.37	28.21	25.61	26.91	28.42	19.87	24.87	22.75
CD (P=0.05)	NS	NS	NS	2.4	NS	NS	NS	1.8
	Bearing Nagpur mandarin orchard							
T_1	18.62	28.04	20.18	24.30	20.80	19.80	20.77	24.10
T_2	20.04	27.82	23.05	27.57	18.86	20.70	20.52	25.02
T_3	21.44	27.08	22.42	22.54	18.25	20.40	19.88	27.34
T_4	27.94	27.82	22.03	18.11	22.78	20.90	20.87	25.75
T_5	29.75	27.05	20.92	17.54	20.56	20.05	23.67	25.83
T_6	24.33	27.36	24.41	22.64	18.91	21.50	25.12	28.75
T_7	31.87	26.82	22.17	20.64	20.27	20.70	20.16	28.54
T_8	24.55	29.26	24.06	21.35	24.03	20.60	21.42	26.31
CD (P=0.05)	NS	NS	NS	1.9	NS	NS	NS	1.5

T_1 - Nagpur mandarin ,T_2 - Nagpur mandarin + cotton ,T_3 - Nagpur mandarin + cotton + soybean,
T_4 - Nagpur mandarin + cotton + blackgram , T_5 - Nagpur mandarin + cotton + groundnut ,
T_6 - Nagpur mandarin + soybean ~ by gram , T_7 - Nagpur mandarin + blackgram ~ by gram
T_8- Nagpur mandarin + groundnut ~ by summer mung bean

3.2 Growth of pre-bearing and bearing Nagpur mandarin

Different type of intercrops influenced the measured growth of Nagpur mandarin in terms of plant height, stock girth, scion girth and canopy volume (Table 2). The increase in plant height, stock girth and scion girth was not significant. However, the canopy volume of the plant was significantly influenced by the various intercropping systems during 2001-2003. The highest increase in plant height (1.04, m) and stock/scion ratio (0.61) was observed in the intercropping treatment in bearing Nagpur mandarin orchard. The increase in plant height, canopy volume and stock/scion ratio was comparatively higher in the intercrops with Nagpur mandarin along with soyabean, blackgram and groundnut followed by gram and summer mung bean. The increase in plant height, canopy volume and stcock/scion ratio was 19.52 m, 19.5 m3 and 0.59 in Nagpur mandarin without cotton and intercrops.

There was no effect of various intercropping treatments on various growth parameters of main crop as shown in (Table 2) except that canopy volume which showed maximum increase (28.81m^3) in the treatment Nagpur mandarin + soybean followed by gram followed by Nagpur mandarin + groundnut followed by summer mung bean and Nagpur mandarin + blackgram followed by gram. Yield was recorded maximum in treatment Nagpur mandarin + soybean followed by gram (20.0 t/ha), however, the effect of various treatments was non-significant. Bearing orchard similar trend of observation was recorded with respect to various growth and yield components in bearing orchard (Table 2). However, the growth and yield were much lower in bearing orchard. In bearing orchard plant height increments in various intercropping combinations were non-significant (Table 2).

Plant canopy volume showed significantly more increase in treatment Nagpur mandarin + blackgram followed by gram (Nagpur mandarin + blackgram followed by gram) (10.66 m^3) followed by Nagpur mandarin + cotton + soybean in the year 2010-2012. There was no significant effect on stock-scion ratio under various intercropping combination in all treatments. The stock-scion ratio was higher in pre-bearing mandarin orchard than bearing mandarin plants. This is due to the establishment of the new plants in the pre-bearing orchard of mandarin.

Table 2
Effect of intercropping treatments on plant growth and yield of pre-bearing and bearing Nagpur mandarin orchards during 2009 –2012

Treatments	Increase in Plant Height (m)	Canopy Volume (m^3)	Stock / Scion ratio	Yield (t/ha)
		Pre-bearing Nagpur mandarin orchard		
T_1	0.28	8.49	0.64	----
T_2	0.44	7.73	0.67	----
T_3	0.53	10.53	0.66	----
T_4	0.35	8.73	0.65	---
T_5	0.37	9.29	0.63	----
T_6	0.26	8.19	0.63	----
T_7	0.24	10.66	0.61	----
T_8	0.43	10.60	0.64	----
CD (P=0.05)	NS	1.24	NS	----
		Bearing Nagapur mandarin		
T_1	0.92	19.52	0.59	12.2
T_2	0.58	17.15	0.66	12.75
T_3	0.64	16.10	0.56	14.56
T_4	0.62	10.99	0.55	15.11
T_5	1.04	27.06	0.57	14.50
T_6	1.01	28.81	0.61	20.00
T_7	0.86	22.95	0.56	12.85
T_8	0.63	23.72	0.55	13.51
CD (P=0.05)	NS	2.45	NS	4.71

T_1 - Nagpur mandarin ,T_2 - Nagpur mandarin + cotton ,T_3 - Nagpur mandarin + cotton + soybean,
T_4 - Nagpur mandarin + cotton + blackgram , T_5 - Nagpur mandarin + cotton + groundnut ,
T_6 - Nagpur mandarin + soybean ~ by gram , T_7 - Nagpur mandarin + blackgram ~ by gram
T_8- Nagpur mandarin + groundnut ~ by summer mung bean

3.3. Growth and yield of intercrops in pre-bearing and bearing mandarin orchard

The plant volume of cotton did not differ significantly among different intercropping combinations in pre-bearing mandarin orchard. The number of bolls per plant and the cotton yield was observed maximum under the treatments involving soybean, blackgram and groundnut compared to cotton alone. The plant volume of soybean did not show any distinct trend. However, number of pods per plants was more (92.60) when soybean was grown with cotton (Nagpur mandarin + cotton + soybean) compared to soybean alone followed by gram (67.07). Length of pod was more in cotton + soybean (3.39 cm) but number of seeds per pod was more in soybean alone followed by gram (2.68). Yield of soybean was more in combination with cotton compared to that when grown alone followed by gram. The volume of plants in blackgram did not show significant difference in the two treatments (Nagpur mandarin + cotton + blackgram and Nagpur mandarin + blackgram followed by gram). The volume of plants in the year 2011-2012 was less due to high incidence of mosaic disease. This had a direct bearing on the number of pods, length of pods, number of seeds per pod and yield of blackgram. The plant volume in groundnut was maximum was similar in both the treatments T_5 and T_8. Similar trend was observed in case of number of pods

per plants. However, the length of pods, number of seeds and yield were significantly more when groundnut was grown with cotton. The plant volume was similar in all the treatment combination of gram yield of gram was more in treatment involving soybean (Table 3). The yield per tree of intercrops during 2010-11 and 2011-12 was influenced by different intercropping systems. Significant difference in intercrop yield was observed in different intercropping treatments during 2010-12. Similar results of increased yield due to intercropping were reported in different mandarins as well as other citrus cultivars (Krishnamurti, 1959, Singh and Bakshi, 1961; Randhawa *et al.,* 1996).

3.4. Soil fertility status and nutrient uptake in Nagpur mandarin orchards

The soil organic carbon in almost all the treatment observed to increase significantly in both pre-bearing and bearing orchards. Considerable higher increase was observed under treatment T_6 and T_7 after two years. The increase is due to addition of organic residues of different intercrops while in no intercrop treatment it remained unchanged. The soil pH value of both orchards remains unaffected due to different intercrops. In bearing orchard decrease in Ec values was observed in T_5, T_6 and T_7 treatments while in pre-bearing orchard it decreased in treatment T_4 (0.34 – 0.27 ds/m^{-1}). In pre-bearing mandarin orchards soil nutrient variation was greater compared to bearing orchards may be because of large space available for growing different intercrops. The nitrogen content among different treatments varies significantly. The decrease was observed in treatment T_2 while the highest increase was observed in T_6. The phosphorus content in all the treatments decreased after two years except in treatment T_4. The potassium content also varied significantly it decreased in T_2 and T_4 treatment while in rest of the treatments it increased. The highest increase was observed in T_3 (270.6 – 328.7 kg ha^{-1}). The soil iron status found to vary significantly among different treatments. The increase was observed in T_1 and T_6 treatments while in treatment T_2 it decreased over the initial values after two years. The manganese content decreased in all treatments after first year, which increases during subsequent years. Considerable decrease in manganese was observed in T_1 treatment. Difference was not much in Zinc content due to different treatments.

The nitrogen uptake in all the treatment increased during the subsequent years. The highest increase was observed in T_6 (Nagpur mandarin + soybean followed by gram (*Chaffa*) (1.76 to 2.24%). In pre-bearing the P uptake decreased in (T_1) Nagpur mandarin (0.13 to 0.10%) and T_2 (Nagpur mandarin + cotton (LRK – 516)) (0.12 to 0.09%) treatments, while in T_5 (Nagpur mandarin + cotton + groundnut (JL – 24)) (0.12 to 0.16%) and T_7 (Nagpur mandarin + blackgram followed by gram) (0.13 to 0.16%) treatment it increases slightly. The potassium uptake in treatments T_1 (Nagpur mandarin), T_2 (Nagpur mandarin + cotton (LRK – 516)) and T_3 (Nagpur mandarin + cotton + soybean (JS - 335)) remained nearly unchanged after the increase in two initial years. In rest of the treatments it increased over the initial content (Table 3). The various micronutrients such as Fe, Mn, Cu and Zn content found to vary significantly among different treatments. The Fe content with the increases during initial two years, it decreased during third year treatments T_1, T_2 and T_3. The manganese content also observed to vary significantly among different treatments. The highest increase in Mn content was observed in T_6 (54.5 to 75.8 ppm) while in substantially decreases (64.5 to 54.2 ppm) was observed after two years. The copper content among different treatments though significantly but it was non-significant during third year. The highest increase in Zinc uptake was observed in T_8 (17.9 to 22.8 ppm) treatment.

The nitrogen uptake found to vary significantly (1.62 to 2.14 %) during 2011 and 2012 among the different treatments. It was highest in the treatment (2.08 %) and T_7 (2.14%) during 2011 and 2012, respectively. In most of the intercrop treatments it observed to increase while in cotton sole intercrop treatment it decreased to small extent. Much variation in phosphorus uptake was not observed among the different treatments. In T_4 (Nagpur mandarin + cotton + blackgram (TAU – 1)) the P content was found to decrease from 0.19 to 0.12% after three years. In most of the intercropping treatments the K content increased after first and second year, while during third year it decreased. The black soils of central India are rich on potassium and luxury consumption by plants may be the reason for the same.

3.5. Fruit quality of bearing Nagpur mandarin

The fruit quality of Nagpur mandarin was also greatly influenced by different main as well as intercrops (Table 4). Different intercropping treatments conserved in-situ soil moisture during the crop growing period resulted in better fruit weight, TSS, acidity and juice content and yield of the fruits. The significant difference was observed in juice content, acidity and TSS. The size of the fruit, peel weight and thickness, number of seeds and segments are

not non-significant. Highest fruit juice content (3.12 %) was observed in the Nagpur mandarin without any intercrops.

Table 3
Effect of different intercropping systems on yield of intercrops during 2009-2012

Treatments	Volume of Plants (m^3)	No. of pods / plants	Yield (kg ha^{-1})
	Pre-bearing Nagpur mandarin orchard		
Cotton			
T_2	0.027	22.44	898.58
T_3	0.027	25.80	975.23
T_4	0.026	24.08	1008.25
T_5	0.025	22.57	893.44
Soybean			
T_3	0.031	92.60	2837.33
T_6	0.029	67.07	1358.77
Black gram			
T_4	0.017	21.80	823.91
T_7	0.014	18.90	545.67
Groundnut			
T_5	0.021	23.18	898.37
T_8	0.019	25.31	814.54
Gram			
T_6	0.009	24.23	453.04
T_7	0.011	25.80	526.94
CD (P=0.05)	0.0052	2.88	27.3
	Bearing Nagpur mandarin orchard		
Cotton			
T_2	0.018	21.47	286.54
T_3	0.013	18.93	275.48
T_4	0.014	18.93	252.93
T_5	0.012	18.28	211.40
Soybean			
T_3	0.011	24.16	390.99
T_6	0.009	22.48	340.35
Black gram			
T_4	0.008	10.11	147.63
T_7	0.007	8.74	67.22
Groundnut			
T_5	0.007	17.66	128.50
T_8	0.008	23.27	139.29
Gram			
T_6	0.002	3.85	123.50
T_7	0.002	3.18	105.84
CD (P=0.05)	0.0019	1.73	18.4

T_1 - Nagpur mandarin ,T_2 - Nagpur mandarin + cotton ,T_3 - Nagpur mandarin + cotton + soybean,
T_4 - Nagpur mandarin + cotton + blackgram , T_5 - Nagpur mandarin + cotton + groundnut ,
T_6 - Nagpur mandarin + soybean ~ by gram , T_7 - Nagpur mandarin + blackgram ~ by gram
T_8- Nagpur mandarin + groundnut ~ by summer mung bean

The highest TSS (13.6 ^{O}Brix) was in the fruits of the Nagpur mandarin + cotton + blackgram intercropping system. The lowest acidity (0.74 5) was tested in the intercropping with Nagpur mandarin + blackgram followed by gram. The ratio of TSS to acidity is highest in the intercropping Nagpur mandarin + blackgram followed by gram (15.95) indicating the sweet mandarin. The TSS to acidity ratio was also high in the intercropping Nagpur mandarin

with cotton + groundnut (14.51) followed by intercropping Nagpur mandarin with groundnut (13.72). The fruit size, TSS, acidity and TSS to acidity ratio was intermediate in the intercropping system of Nagpur mandarin with cotton along with soyabean, blackgram and groundnut. The fruit size was larger in the intercrop of Nagpur mandarin + groundnut followed by gram (6.36 cm). The mandarin fruit size was lower in Nagpur mandarin alone cropping system. Similar results were observed in Nagpur mandarin (Singh and Bakshi, 1961, Paslawar et al., 1999). Peel weight, peel thickness, number of segments number of seeds, fruit and juice percentage. Fruit size was unaffected by various intercropping treatments (Table 3). Total soluble solids (TSS) were significantly more in treatment Nagpur mandarin + cotton + blackgram (13.61%) compared to all other treatments in 2001-2002. In 2002-2003 it was more in treatment Nagpur mandarin + cotton + soybean and Nagpur mandarin + cotton + groundnut. Fruit vitamin C was unaffected with intercropping systems in Nagpur mandarin orchards.

Table 4
Effect of different intercropping systems on fruit quality of Nagpur mandarin during 2009-2012

Treatment	Diameter of fruit (cm)	Peel		No. of		Juice			
		Weight. (g)	Thickness (mm)	seeds	segments	Percentage (%)	T.S.S (^{O} Brix)	Acidity (%)	TSS/ acidity ratio
T_1	5.87	57.3	1.87	10.29	8.03	43.12	11.55	0.97	11.90
T_2	6.04	62.3	1.76	9.95	8.73	39.64	11.62	0.97	11.97
T_3	5.76	48.7	1.76	8.94	7.97	41.06	12.80	0.96	13.34
T_4	5.84	55.4	1.77	10.02	7.61	43.03	13.61	1.03	13.21
T_5	5.74	58.0	1.75	10.06	9.01	40.92	12.63	0.87	14.51
T_6	6.14	57.1	1.89	10.18	8.56	41.74	11.41	0.84	13.58
T_7	6.13	68.5	1.77	9.96	9.01	39.65	11.81	0.74	15.95
T_8	6.36	63.0	1.93	10.06	7.67	37.41	11.53	0.84	13.72
CD (P=0.05)	NS	NS	NS	NS	NS	1.65	1.61	0.41	0.43

T_1 - Nagpur mandarin ,T_2 - Nagpur mandarin + cotton ,T_3 - Nagpur mandarin + cotton + soybean,
T_4 - Nagpur mandarin + cotton + blackgram , T_5 - Nagpur mandarin + cotton + groundnut ,
T_6 - Nagpur mandarin + soybean ~ by gram , T_7 - Nagpur mandarin + blackgram ~ by gram
T_8- Nagpur mandarin + groundnut ~ by summer mung bean

4. Conclusion

In bearing orchard plant growth of Nagpur mandarin was not affected by the intercrops. In pre-bearing orchard plant height and stock-scion ratio of Nagpur mandarin plants was not affected by various intercrops whereas canopy volume was recorded maximum in the treatment Nagpur mandarin + blackgram followed by gram (10.6 m^3). Cotton can be grown in 5 and 3 in space in between the mandarin rows. Cotton with the other intercrops such as soyabean, blackgram and groundnut can be sown in between centrally grown cotton and in between Nagpur mandarin as a strip. The plant canopy volume of Nagpur mandarin shown maximum increase of 28-81 m^3 in Nagpur mandarin + soyabean followed by gram. The highest Nagpur mandarin yield 20.0 t/ha (72.3 kg/tree) was recorded in the intercropping of Nagpur mandarin + soyabean followed by gram. Growth and yields of the intercrops in the bearing orchard were lower than those under pre-bearing orchard. In bearing orchard the treatment combination of Nagpur mandarin + soyabean followed by gram resulted in maximum yield of Nagpur mandarin i.e. 20.0 tonnes per hectare. The total soluble solids (TSS) to acidity ratio was more in Nagpur mandarin + black gram followed by gram (15.95) and Nagpur mandarin + cotton + groundnut (14.51). The fruit acidity and juice percent were also significantly affected High soil moisture were observed in intercrops of soyabean and groundnut. The maximum cotton yield was under treatment of intercropping soyabean, black gram and groundnut compared to cotton alone. The number of pods per plants was more in soyabean grown with cotton (92.6) as compared to soyabean alone. This study reveled that the intercropping system with cotton + soyabean or

cotton + black gram in the interspaces of pre-bearing and bearing mandarin improved the yield as well as sustainability of mandarin as well as the production of intercrops. Net price-return of different intercrops was higher in pre-bearing orchard compared to bearing orchard. The economical return of mandarin crop was higher in the intercropping treatment combination of Nagpur mandarin + soybean followed by gram as compared to rest of the other treatments.

References

Chadda, H.P., Randhawa, J.S., Bakshi, J.C., Parihar, S.S., 1969. Effects of intercropping characteristics in young citrus orchards on soil properties. *Paper presented at Seminar on Advances in Fruit Research* , Ludhiana, April 1969.

Chadda, K.L., Randhawa, N.S., Bindra, O.S., Chohan, J.S., Knorr, L.C., 1970. Citrus decline in India. *A publication of Punjab Agricultural University,* Ludhiana, p 50-55.

Chundawat, B.S., 1993. Intercropping in orchards In : Chanda, K L. (Ed). *Advances in Horticulture* Vol.2. Malhotra publishing House, New Delhi, PP. 763 – 75.

Gill, A.S., 1999. Agri - silvi - horticultural studies with mandarin orchards. *Proceedings of International symposium on Citriculture.* November 23-27, 1999. NRCC, Nagpur, India, p 680-684.

Gonge, V.S., Kale, P.B., 1997. Effect of intercropping on growth of citrus during pre-bearing stage. *Abstracts*. *National Symposium on Citriculture,* NRCC, Nagpur, 17–19 November, p30.

Huchche, A.D., Shivankar, V.J., Shirgure, P.S., Marathe, R.A., Singh, S., Mane, P., Kadao, S., Patil, S., 2006. Legume based intercropping systems for Nagpur mandarin (*Citrus reticulata* Blanco). Paper presented in the National Symposium on Citriculture : A road map at ICAR research complex for NEH region, Umiam, Meghalaya during 22nd – 24st February, 2006. p-55

Krishnamurti, S., 1959. Intercropping, cover cropping and mulching of orchards. *Indian J. Hort.,* **16**, 221-28.

Paslawar, A.N., Dalal, S.R., Golliwara, V.J., Khobragade, R.I., 1999. Intercropping in Nagpur mandarin (*Citrus reticulata* Blanco). *Proceeding of International symposium on Citriculture.* November 23-27, 1999. NRCC, Nagpur, India, p 676-679.

Randhawa, N.S., Bhumbla, D.R., Dhingra, D.P., 1996. Citrus decline in the Punjab –A review. *Punjab Hort. J.* **6,** 35-44.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2000. Water management in citrus – A review. *Agricultural Reviews* 21 (4) , 223-230.

Shivankar, V.J., Singh, S., Huchche, A.D., Shirgure, P.S., Das, A.K., Mane, P.N., Patil, S.P., 2004. Effect of intercropping systems on insect pests complex of Nagpur mandarin (*Citrus reticulata* Blanco). Abstract International Citrus Congress held at Agadir, Morocco during 15-20th February, 2004.

Singh, K.K., Bakshi, J.C., 1961. Intercropping of citrus orchards. I. Effect of intercropping of cotton on growth of young sweet orange trees. *Indian J. Hort.* 18**,** 130-34.

Singh, S., 1999. Citrus in India. *Proceedings of International Symposium on Citriculture,* held during 23 -27 November 1999 at National Research Centre for Citrus, Nagpur, p 278-303.