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Evaluation of intercropping corn, soybean and cowpea with Washington navel orange orchard under different N fertilizer levels

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ABSTRACT

Three separate experiments were conducted at Experimental Farm, Horticulture Department, Faculty of Agriculture, Moshtohor, Benha Univ., Egypt at 2014 and 2015 seasons. The aim of this study was to evaluate some intercropping systems of corn, soybean and cowpea with Washington navel orange at different N fertilizer levels versus solid ones. Soil fertility, weed control, competitive relationships and biological & economic evaluations of the intercropping system were considered in the study. Experimental design was RCBD with three replicates. The treatments of each experiment were including intercropped one of the three corn, soybean or cowpea with Washington navel orange orchards at four levels of nitrogen fertilization (0, 25, 50 and 75%) of the recommended fertilizer level of corn, soybean or cowpea as well solid culture of each crop. The obtained results from three trials revealed that intercropping legume crops with Washington navel orange trees increased available NPK (mg kg^{-1}) content in soil trees as well as more effective in suppress weeds. Superiority of fruit yield and quality of monoculture over intercropped orange orchards were detected. But statistical analysis indicated that orange orchards with legumes as intercrop (soybean or cowpea) at 50 and 75% of N levels produced significantly higher fruit yield and enhanced fruit quality traits compared with monoculture of orange tree. Intercropping three secondary crops under orange tree was significantly decreased crop growth rate (CGR), light intensity %, yield and yield components over than monoculture. Increasing levels of N fertilization from 0 up to 75% significantly increased and enhanced all studied traits for main and secondary crops, except light intensity %. The highest values of nitrogen use efficiency (NUE) were achieved at 75% N fertilization in corn and soybean, but at 50% N levels in cowpea. All intercropping treatments increased total productivity of unity area, except unfertilized corn/orange intercropping system as well orange trees was dominant and had higher competition ratio than corn, soybean or cowpea. Polyculture of orange orchards is a successful technology to increase land equivalent ratio (LER), land equivalent coefficient (LEC), total cereal units (CUs), total return as well as monetary advantage index (MAI). The increases in total return were 9.05, 18.96 and 19.84% at 75% N level over solid orange, while MAI values were L.E. 6346, 7959 and 9652 in orange orchard intercropped with corn, soybean and cowpea, respectively, as average of both seasons.

Key words: polyculture, Washington navel orange orchards, N fertilization, corn, soybean, cowpea, LER, CUs.

Introduction

In Egypt, fruit crops has become an important sector in agricultural. It occupied 1.78 million feddans which represented 11.36% of the total cultivated area in 2014 season. Citrus orchards rank the first position among fruit crops, followed in descending order by mangos, olives, grapevines and date palms (Statistics of the Ministry of Agriculture and Land Reclamation, 2014). Washington navel orange (*Citrus sinensis* L. Osbeck) is considered the most popular and widespread citrus variety in Egypt, for its delicious, taste and nutrition, besides being rich in vitamin C and minerals. Due to wider spacing between the trees and the large unutilized inter-space about 60 to 70 % can be exploited for growing inter and mixed crops successfully to increase land use efficiency, farmers income, food security, reduction of soil erosion, pest, disease and weed control (Mousavi and Eskandari, 2011; Ahmed- Nagwa *et al*., 2014 and Ijaz *et al*., 2014).

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The role of legumes in soil fertility enrichment by fixing nitrogen biologically, high nutrient availability in the soil due to reducing soil pH and consequently, the improved nutrient acquisition by the plants to govern the yield and quality enhancement is well-known compared to highly exhaustive crops like wheat and maize as intercrop in citrus orchards (Yan *et al.,* 1996; Srivastava *et al.,* 2007; Abdel-Aziz *et al.,* 2008 and Mousavi and Eskandari, 2011). Nitrogen concentration in the orchard soil was improved due to growing of leguminous crops, while phosphorus and potassium were depleted in all cases (Srivastava *et al.,* 2007). On the other hand, Zhou *et al.,* (2009) concluded that the total cumulative amount of P in soybean was remarkably greater under soybean monoculture than under soybean-orange intercropping, while the opposite results were true in orange monoculture.

Intercropping citrus tree provided excellent weed suppression, where intercropping can be used as an effective weed control strategy by increasing shade and crop competition with weeds through tighter crop spacing (Gold *et al.,* 2006; Linares *et al.,* 2008 and Bauri *et al.,* 2010).

Intercropping in fruit orchards is a common practice in many countries. Aiyelaagbe (2001) concluded that intercropping orange tree with cassava + maize prevented early fruit set and significantly decreased fruit yield of sweet orange. Forty-two months after transplanting sweet orange, sole orange, orange + maize following by cowpea, and sweet orange + cassava had 1.63, 1.45, and 0.05 ton ha^{-1} citrus fruit,, respectively (Olanyan and Fagbayide, 2007). Srivastava *et al.,* (2007) reported that citrus orchards showed superiority of monoculture (68.5 kg tree^{-1}) over intercropped (51.4 kg tree^{-1}) orchards. While, citrus orchards with legumes as intercrop (soybean and chickpea), produced significantly higher fruit yield (72.2 kg tree^{-1}) as compared to orchards without intercrops (68.5 kg tree^{-1}). French-beans intercropped with lemon trees (*Citrus limon*) proved to be the best yield (ton ha $^{-1}$) of lemon and the highest gross return (Hnamte *et al.,* 2013). Shirgure (2012) revealed that the highest Nagpur mandarin yield 20.0 ton ha^{-1} (72.3 kg tree^{-1}) was recorded in the intercropping of Nagpur mandarin + soybean followed by gram. 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. Polyculture significantly increased land equivalent ratio (LER), net return and monetary advantage index (MAI) for farmers (Osman *et al*., 2011; Shoeib, 2012; Ahmed- Nagwa *et al*., 2014 and Gebru, 2015). Crop sequence including Egyptian clover in winter followed by maize/soybean intercropping had the highest total cereal units fed^{-1} over than clover in winter followed by maize or soybean alone (El-Maihy- Amira, 2011).

A major factor in successful farming is the grower's ability to manage N efficiently (Zekri and Obreza, 2013). Three years study indicated that N, P, and K application significantly promoted citrus growth in young stage and improved both fruit yield and quality as well (Wei *et al.,* 2004 and Morgan *et al.,* 2009). Application of 250 g of ammonium sulfate for every tree in soil during June to improve the quantity and quality characteristics as well as increased yield of sweet lime than 500 g per tree in calcareous soil (Aboutalebi, 2013).There was a decreasing pattern in nitrogen use efficiency values with increasing fertilizer rates, indicating that crop production could be sustained with lower fertilizer applications (De Juan *et al.,* 2005). Average plant height, dry matter accumulation and crop growth rate of maize were significantly increased with increasing in the rate of N fertilizer from 90 up to 135 kg N ha^{-1} (Onasanya *et al.,* 2009 and Amujoyegbe and Elemo, 2013). Leaf area index and light interception of solar radiation were reduced by a decrease in individual leaf area, when no N or 90 kg ha^{-1} were applied compared to 225 kg N ha^{-1} (Puntel, 2012).

Therefore, this study aims to assess the impact of intercropping systems and N application rates on growth, yield and quality traits of Washington navel orange tree, corn, soybean and cowpea in polyculture systems versus monoculture as well as their effects on weed control, soil fertility and economic return.

Material and Methods

Study site description:

The work was conducted on fruitful trees, eleven-year old, Washington navel orange budded on sour orange rootstock, under flooding irrigation surface, at Experimental Farm, Horticulture Department, Faculty of Agriculture, Moshtohor, Egypt, during 2014 and 2015 seasons. The experimental soil was clay in texture. Chemical analysis of the soil (0 – 30 cm) were EC (0.62) pH value (7.14), organic matter (1.164 %), available N, P and K were 49.50, 17.77 and 492.50 ppm, respectively.

Experimental design:

Three annual crops namely corn, soybean and cowpea interplanting under Washington navel orange trees in three simple experiments A, B and C, respectively. To assess productivity and quality of each crops, soil fertility, weed control, nitrogen use efficiency, competitive relationships, total cereal units and economic evaluation under polyculture system compared to monoculture system. Experimental design was RCBD with three replicates. Under polyculture system each replicate was represented by one tree, plot area was 25 m^2 (5x5m) while, monoculture of corn, soybean or cowpea were established outside the shade of any tree.

Each experiment was included five treatments as follows:

1. Interplanting corn, soybean or cowpea with orange orchard without nitrogen fertilization (zero % N) of the recommended fertilizer level for annual crop.
2. Interplanting corn, soybean or cowpea with orange orchard at 25% N of the recommended fertilizer level for annual crop.
3. Interplanting corn, soybean or cowpea with orange orchard at 50% N of the recommended fertilizer level for annual crop.
4. Interplanting corn, soybean or cowpea with orange orchard at 75% N of the recommended fertilizer level for annual crop.
5. Orange tree, corn, soybean or cowpea monoculture and N level were applied as the recommended level for each crop as control.

Nitrogen application levels, of the recommended fertilizer for corn, soybean or cowpea were 120, 60 and 60 kg fed^{-1} applied only to the understory crops at equal two doses, respectively, and proportionate with area of each crop. While, Washington navel orange trees were received 165Kg N fed^{-1} added at three doses 67, 41 and 57Kg N fed^{-1} in first February, May and September, respectively, around trunk of trees only.

Washington navel orange trees, corn, soybean and cowpea establishments and managements:

The orange trees were planted with a spacing of 5m × 5m about 168 trees fed^{-1}. The trees were of almost uniform vigor and received the customary practices for pruning, fertilization, irrigation, and weed and pest control. The main crop (orange trees) were planted in the furrows and the secondary crops (corn, soybean and cowpea) on the ridges between tree rows at spacing 60 cm apart, this arrangement ensures that no land area is lost. The secondary crops were planted on May 13^{th} and 10^{th} in 2014 and 2015 seasons, respectively. Corn hybrid (yellow S.C 2066) were planted in one side of the ridges and were thinned to one plant/hill spaced at 30 cm, soybean seeds (cv. Giza 111) were planted in hills on the two sides of the ridge and were thinned on two plants/hill spaced at 20 cm meanwhile, cowpea seeds (cv. Buff) were grown in one side of the ridge and thinned to two plants/hill at 20 cm in multiply and pure stand for each crops.

Studied traits:

Soil samples were taken after harvesting of corn, soybean and cowpea. It was taken horizontally at a distance 200 cm from tree trunk and vertically at a depth of (0 – 30 cm) from soil surface. Soil organic matter content was analyzed by (Black *et al.,* 1965), soil content of available NPK according to (Jackson, 1973). Also, after 55 days from planting, weeds were pulled from one meter square for each plot. Fresh and dry weight of weeds were determined of all experimental plots and classified. Sample of weeds were air dried then dried at 105°C in a forced air oven for 24 hours to estimated dry weight.

The following traits for orange trees, corn, soybean and cowpea were:

Orange trees:

Fruit yield (ton fed^{-1}) was estimated as average of fruit weight (kg) x average of fruit number $tree^{-1}$ x 168 trees fed^{-1} x 1/1000. Fruit physical properties were determined as fruit size (cm^3), polar & equatorial diameters (cm) and juice volume (cm^3).

Fruit chemical properties i.e. fruit juice total soluble solids (TSS%) using a Carl Zeiss hand refractometer, juice total acidity % as citric acid was assayed by titration against NaOH (0.1N) and fruit juice Vitamin C content "ascorbic acid" (mg/100ml fruit juice) determined by titration with 2-6 dichlorophenol indophenol dye were determined according to A.O.A.C., 1990.

Corn, soybean and cowpea:

(A): At growth period:

Light intensity (lux) inside corn, soybean or cowpea canopy at middle of the plant was recorded by Lux-meter apparatus at mid–day from each plot and expressed as percentage from light intensity (100%) measured above the plants.

Crop growth rate (CGR) values were estimated at 15-day interval as described by Hunt (1978) for corn and soybean (45, 60, 75 and 90 days after planting DAP), meanwhile, for cowpea measured weekly at (42, 49 and 56 DAP) before the first cut only. The following formula was used: Crop Growth Rate g $week^{-1}$ (CGR) = (W2 − W1)/ (T2 − T1), where W1 is total dry weight at time T1 and W2 is the total dry weight at time T2.

(B): At harvest:

Corn (experimental A): plant height (cm), No. of ears $plant^{-1}$, 100-grain weight, grain and straw yields ton fed^{-1} and grain protein content% were estimated for corn.

Soybean (experimental B): plant height, No. of branches and pods $plant^{-1}$, seed index, seed and straw yields and seed protein content (%) were determined.

Cowpea (experimental C) traits were plant height (cm), No. of branches $plant^{-1}$, leaf/stem ratio $plant^{-1}$ and fresh and dry forage yields ton fed^{-1}. The first cut was after 60 days of planting while second cut was after 45 days from the first cut.

Nitrogen use efficiency (NUE) for each treatment was determined using the agronomic efficiency (AE) indices (Dobermann, 2007), AE = (Y – Yo) / F

Where F = amount of (fertilizer) nutrient applied (kg/fed), Y = Crop yield with applied nutrients (kg/fed) and Yo = crop yield (kg/fed) in a control treatment without N.

Competitive relationships and monetary advantages:

1-Land equivalent ratio (LER) was estimated according to Mead and Willey (1980): LER= (Yab / Yaa) + (Yba / Ybb). Where, Yaa and Ybb are yields as sole crops of a (tree) and b (corn, soybean or cowpea) and Yab and Yba are yields as intercrops of a and b, respectively . Values of total LER greater than 1.0 are considered advantages, while values of total LER less than 1.0 are considered disadvantages.

*2-Land equivalent coefficient (LEC):*A measure of interaction concerned with the strength of relationship was calculated thus, LEC = La × Lb

Where, La = LERa of main crop and Lb = LERb of intercrop (Adetiloye *et al.,* 1983). For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%, that is, a yield advantage is obtained if LEC value exceeds 0.25.

*3-Aggressivity (Agg):*It was calculated as: Aab=(Yab/Yaa xZab) – (Yba/Ybb x Zba). Where, Yaa and Ybb are yields as sole crops of a and b as well as Yab and Yba are yields as intercrops of a and b. Zab and Zba are the sown proportions of a and b, respectively. If Aab = 0, both crops are equally competitive, if Aab is positive, a is dominant, if Aab is negative a is dominated crop (Mc-Gilichrist 1960).

4-Competitive ratio (CR): was calculated by the following formula as given by Putnam *et al.,* (1984). It indicates the number of times by which one component crop is more competitive than the other. CR = CRa + CRb

CRa = LERa / LERb X Zba/ Zab. If Ra < 1, there is a positive benefit and the crop can be grown in association; if Ra > 1, there a negative benefit. The reverse is true for Rb.

Total cereal unit (CUs): was conducted for two interplanting crops, citrus fruits and corn, soybean or cowpea crop. Cereal units were proposed by Brockhaus (1962) to express agronomic gains from crops based on constituents of products either main products or by-products. Cereal units for crops, estimated per 100kg, as follow: citrus fruit = 0.25 unit, grain maize = 1 unit, seed soybean= 1.5 units, fresh forage of cowpea= 0.14 unit, straw corn =0.15 unit and straw soybean = 0.25 unit.

Total return and monetary advantage index (MAI): Total return was calculated according to the prices of main and by-products for fruit orange, corn, soybean or cowpea crops according to the official prices issued by the Ministry of Agriculture and Reclamation (2014&2015 seasons), except cowpea fresh forage assessed on the basis of the price values of this area L.E. 235per ton.

Monetary advantage index MAI was calculated according to Willey (1979).

MAI= [Value of combined intercrops x (LER–1)]/LER

Statistical analysis: Data was performed using computer software MSTAT-C and mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% (Gomez and Gomez, 1984).

Results and Discussions

The first experiment (A):

Impact of interplanting corn with orange trees and N application on:

A1: Soil NPK content:

Data presented in Table (1) indicate that soil content of available NPK was remarkably greater in corn pure stand over than corn intercropping with Washington navel orange. While, interplanting corn with orange trees increased soil content of available N in orange orchards when N fertilization was applied at 50 and/or 75% of N levels only but without significant differences. However, available P content in corn/ orange orchard was not significantly affected in both seasons whereas, considerable difference in the soil content of available K in orange intercropping compared to solid orange. These results are in agreement with the findings of Olanyan and Fagbayide (2007). They reported that there was a buildup of nitrogen (N) and organic carbon in the soil for all the sweet orange intercrops after the third year of the study. The cropping mixture of sweet orange+ maize/ cowpea and sole sweet orange had the highest N value of 0.70 g N/kg soil as compared to 0.30 g N/kg pre-planting. Sweet orange intercropped with maize/cowpea had the highest phosphorus (P) level of 0.17%, followed by sole sweet orange, while sweet orange intercropped with cassava or pineapple had the lowest P values. Potassium (K) was in the adequate range in the sweet orange leaves for all the cropping systems.

Table 1: Impact of interplanting corn and N application on orange soil content of NPK available (mg kg^{-1}) after harvesting corn in 2014 and 2015 seasons.

Treatment	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}
	2014 season			2015 season		
Solid Tree	49.09	16.74	496.45	52.60	17.66	526.45
Solid corn	53.90	17.11	620.56	56.70	23.50	571.57
A system + N1	39.00	16.02	525.44	51.10	23.85	505.04
A system + N2	47.10	19.92	500.97	52.50	22.29	519.31
A system + N3	51.50	16.23	563.11	53.50	21.30	506.25
A system + N4	52.70	16.54	538.10	54.60	19.48	521.77
LSD at 5%	6.27	N.S	41.53	3.69	N.S	39.54

A systems interplanting corn with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for corn crop.

A2: Weeds prevalence in Washington navel orange orchards:

Data in Table (2) indicate that interplanting corn with orange trees significantly decreased fresh and dry weights of grassy, broad leaved and total weeds under any N application levels fed^{-1} compared to solid orange. Corn interplanting with orange orchard reduces weight of total fresh and dry weeds by (61.90 and 50.09%) compared with solid trees, as average of both seasons, respectively. Increasing N levels up to 75% fed^{-1} (N4) significantly depressed weight of total fresh and dry weeds compared with unfertilized treatments (N1) by 47.40 and 48.75%, respectively, as average of two seasons. Intercropping can be used as an effective weed control strategy by increasing shade and crop competition with weeds through tighter crop spacing due to high plant populations compared with solid orange. These results are in accordance with those obtained by Gold *et al.,* (2006); Linares *et al.,* (2008) and Bauri *et al.,* (2010).

Table 2: Impact of interplanting corn and N application on fresh and dry weights of grassy, broad leaved and total weeds (g m^{-2}) under orange orchards in 2014 and 2015 seasons

Treatment	Fresh grassy weeds (g m^{-2})	Fresh broad weeds (g m^{-2})	Total fresh weeds (g m^{-2})	Dry grassy weeds (g m^{-2})	Dry broad weeds (g m^{-2})	Total dry Weeds (g m^{-2})
	2014 season					
Solid Tree	499.47	1002.10	1501.60	140.41	232.17	372.58
Solid corn	185.08	218.84	403.92	49.69	52.52	102.21
A system + N1	209.33	273.67	483.00	60.07	68.67	128.75
A system + N2	227.67	256.67	484.33	62.90	61.90	124.80
A system + N3	111.33	217.00	328.33	33.29	52.11	85.40
A system + N4	192.00	128.00	320.00	52.52	31.38	83.89
LSD at 5%	69.84	46.12	90.58	55.38	17.34	80.17
	2015 season					
Solid Tree	314.80	412.97	727.77	88.77	94.76	183.35
Solid corn	190.42	190.83	381.25	49.25	43.82	92.33
A system + N1	231.67	255.00	486.67	73.70	60.22	133.93
A system + N2	200.00	220.00	420.00	53.68	50.56	103.74
A system + N3	145.00	195.00	340.00	40.74	43.93	84.69
A system + N4	95.00	93.33	188.33	26.07	22.11	48.20
LSD at 5%	23.17	51.20	56.19	14.65	29.81	33.76

A systems interplanting corn with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for corn crop.

A3: Fruit characters, yield and quality of Washington navel orange trees:

Data presented in Table (3) indicate that corn/orange intercropping system is considered more negative effect on all studied characters of orange trees compared with pure stand. Intercropping orange plots without applied N fertilizer fed^{-1}, it significantly reduced fruit characters (weight, dimensions and size), juice volume and fruit quality (TSS% and vitamin C content) except acidity%, relative to other treatments. However, intercropping corn with orange orchards at 75% N level fed^{-1} enhanced all these traits compared with solid culture but differences below level of significance.

Similarly, minus effect of intercropping on number and weight of fruit tree^{-1} and fruit yield fed^{-1} was clear in plots unfertilized with N compared with high N levels applied (N4). Interplanting corn under orange trees at zero, 25, 50 and 75% levels were significantly decreased fruit yield fed^{-1} by 34.76, 26.12, 18.03 and 12.89% and 33.64, 26.01, 15.34 and 8.77% in first and second seasons compared to solid orange, respectively. These results might be attributed to interspecific competition between the intercrop components for growth resources (light, water, nutrients, air, etc.) as well as corn consider stressful crop. These results are in agreement with those reported by Srivastava *et al.,* (2007); Mousavi and Eskandari (2011) and Gebru (2015).

Table 3: Impact of interplanting corn and N fertilization on fruit yield, fruit physical and chemical properties of Washington navel orange in 2014 and 2015 seasons.

Treatment	Fruit weight (g)	Fruit dimensions diameter of		Fruit Size (cm^3)	Juice volume (cm^3)	TSS (%)	Acidity (%)	Vitamin C mg/100ml	No. of fruit/ Tree (No)	Fruit weight /Tree (Kg)	Fruit yield /Fed (Ton)
		Polar (cm)	Equ. (cm)								
	2014 season										
Solid Tree	251.38	7.99	7.73	248.67	86.67	12.00	0.970	52.12	155.99	39.21	6.588
A system+N1	199.39	7.42	7.13	180.00	63.33	9.00	1.067	42.56	128.30	25.58	4.298
A system+N2	220.78	7.55	7.35	206.67	65.83	10.67	0.917	48.62	131.21	28.97	4.867
A system+N3	245.67	7.67	7.52	220.83	80.00	11.67	0.900	51.02	133.01	32.14	5.490
A system+N4	254.92	8.00	7.78	250.00	91.01	12.17	0.833	54.93	134.00	34.16	5.739
LSD at 5%	4.97	0.41	0.45	27.33	6.95	0.70	0.236	3.50	4.20	3.49	0.635
	2015 season										
Solid Tree	253.07	8.99	7.90	252.17	90.33	11.33	1.003	53.33	157.20	39.78	6.683
A system+N1	198.14	7.25	6.98	182.50	68.33	9.00	1.030	46.67	133.23	26.40	4.435
A system+N2	222.11	7.80	7.13	210.00	76.67	10.33	0.944	51.67	132.51	29.43	4.945
A system+N3	244.78	8.41	7.59	233.33	86.67	10.67	0.953	53.67	137.58	33.68	5.658
A system+N4	255.56	9.00	8.16	257.50	94.17	11.50	0.883	55.00	142.01	36.29	6.097
LSD at 5%	4.53	0.79	0.24	6.69	8.57	0.96	0.241	4.93	3.25	2.72	0.440

A systems interplanting corn with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for corn crop.

A4: Growth, yield components, yield and grain protein content% of corn as well as nitrogen use efficiency (NUE):

Growing corn under orange orchard at different N application levels significantly affected on growth and yield components as shown in Table (4). Polyculture system of corn/orange tree significantly diminished values of crop growth rate (CGR), plant height, No. of ears plant^{-1}, grain weight plant^{-1} and 100-kernel weight. However, light intensity % at middle of corn plants significantly increased in polyculture system over monoculture as shown in Table (4). Under polyculture system increasing N levels from zero (N1) up to 75% (N4) level fed^{-1}, of the recommended fertilizer level of corn, significantly enhancing all studied traits, except light intensity %. The highest values of these traits were achieved at 75% N (N4) followed by 50% (N3) levels fed^{-1}, the opposite trend was true for light intensity% (Table, 4). Similar results reported by by Zardari *et al.,* (2013) and Choudhary *et al.,* (2014). They found that plant height, plant dry matter, chlorophyll content and crop growth rate were significantly greater in sole crop than the intercropping systems. Keating and Carberry (1993) mentioned that differences in vertical arrangement of foliage and canopy architecture of intercrop components, may lead to more PAR interception by intercropping compared with sole crops.

A general analysis of data indicate that grain and straw yields fed^{-1} as well as protein content (%) were significantly influenced by cropping systems and N fertilizer applications (Table, 4). Interplanting corn with orange orchard significantly decreased grain yield over than pure stand by 63.24, 59.34, 55.79 and 49.13% at different levels of N fertilization zero, 25, 50 and 75% as average of the both seasons, respectively. Similarly, straw yield and protein content (%) of corn grains reduced resulting of interplanting corn with orange orchards under different N levels. However, straw yield and protein content (%) of corn significantly increased due to increasing N levels up to 75% in the two seasons. Grain yield of maize (69.99 q ha^{-1}) was significantly greater in sole crop than the intercropping systems (Zardari *et al.,* 2013 and Choudhary *et al.,* 2014). Average plant height, dry matter accumulation and crop growth rate of maize significantly increased by increasing N fertilizer from 90 up to 135 kg N/ha (Onasanya *et al.,* 2009; Puntel, 2012 and Amujoyegbe and Elemo, 2013).

Data listed in Table (4) clearly show that the highest value of nitrogen use efficiency (5.74 and 4.23) was detected by applying N fertilizer at 75 % in two seasons. While, the lowest value of NUE was achieved at 25% N level, except in 1st season. This result may be due to corn highly exhaustive crop and need greatest amount of N (Yan *et al.,* 1996; De Juan *et al.,* 2005; Srivastava *et al.,* 2007 and Mousavi and Eskandari, 2011).

Table 4: Impact of interplanting corn and N application on growth, yield and its components of corn grown under orange orchards in 2014 and 2015 seasons.

Trait / Treatment	Crop growth rate (CGR) (g/ week) at 45-60 days	60-75 days	75-90 days	light intensity (%)	Plant height (cm)	Ears/ plant (No)	Grain weight /plant (g)	100-grain weight (g)	grain yield/ fed (ton)	Straw yield/ fed (ton)	Grain protein content %	N use efficiency kg G /kg N
	2014 season											
Solid corn	42.13	59.13	37.80	8.47	250.50	1.152	158.53	30.58	3.152	4.217	9.59	-
A system + N1	25.86	29.47	21.51	15.77	198.00	0.917	116.79	25.10	1.072	1.981	6.80	-
A system + N2	31.56	42.00	25.18	13.45	211.30	0.977	134.17	25.98	1.233	2.220	7.46	5.37
A system + N3	34.59	48.23	30.05	10.96	220.00	1.140	146.41	27.70	1.354	2.267	8.04	4.70
A system + N4	36.38	55.82	33.34	9.85	241.70	1.147	156.60	32.05	1.589	2.402	8.88	5.74
LSD at 5%	1.51	2.41	2.78	1.04	7.90	0.063	6.76	0.41	0.215	0.311	0.29	0.88
	2015 season											
Solid corn	48.05	60.72	37.72	9.27	249.67	1.158	164.11	31.90	3.211	4.266	10.01	-
A system + N1	29.47	36.03	19.41	14.97	207.73	1.020	124.41	26.00	1.267	2.138	7.78	-
A system + N2	39.06	44.51	27.20	13.13	214.07	1.037	134.86	26.53	1.354	2.184	8.25	2.90
A system + N3	41.72	48.95	32.18	10.29	236.33	1.154	152.89	28.00	1.459	2.311	8.57	3.20
A system + N4	43.66	56.27	34.77	9.72	253.87	1.150	157.89	30.49	1.648	2.466	9.42	4.23
LSD at 5 %	1.87	2.58	2.16	0.81	7.31	0.054	4.02	1.22	0.198	0.221	0.21	0.33

A systems interplanting corn with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for corn crop.

A5: Competitive relationships:

Interplanting corn with orange orchards under all different levels of N application increased Land equivalent ratio (LER) and Land equivalent coefficient (LEC) over than 1.0 and 0.25, in both seasons except corn plots untreated with N fertilization in 1st season only as shown in Table (5). This means that intercropping corn under orange orchards achieved yield advantages and showed efficient utilization of land resource by growing both crops together. Orange tree was dominant and had positive sign while corn was dominated. Orange trees possess competitive ratio (CR) higher than that in corn when it was intercropped together it indicating higher competitiveness of orange than the corn. Increasing N levels from 0 up to 75% enhanced LER and LEC by 38.61 &100% and 34.69 & 80.77% in both seasons, respectively. However, CR values did not affected by increasing N fertilization levels. The result here was in accordance with those obtained by Zardari *et al.,* (2013) and Choudhary *et al.,* (2014) on maize.

A5: Cereal units (CUs), total return and monetary advantages Index (MAI):

Given the price change from one season to another, the biological evaluation (CUs) considered accurate assessment of cropping systems over than economic evaluation**.** Intercropping corn with orange trees at different N fertilization levels increased total CUs by (29.22 and 29.68 units) relative to orange pure stand (16.47 and 16.71), respectively, in the two seasons. Increasing N application from zero up to 75% significantly increased cereal unit fed^{-1} by about 77.52% combined over both seasons as shown in Table (6). These results are in agreement with those reported by El-Maihy-Amira (2011).

Data in Table (6) reveale that intercropping corn with orange trees at 50 and 75% N levels fed^{-1} improved total return (L.E. 20598 and 22164 fed^{-1}) over solid culture of orange tree as well as MAI values were (L.E. 4424 and 6346 fed^{-1}), respectively, in both seasons. On the other hand, interplanting corn under orange trees without N fertilization did not achieve any monetary advantage from intercropping in first season only. This result may be due to adversely effect of corn on fruit yield. Shoeib (2012) concluded that intercropping of clover, peas, onion and Japanese turnip in grapevines increased the income (L.E./fed) by about 8.5, 51.2, 61.4 and 47.1 % compared to sole vines as average of both seasons.

Table 5: Impact of interplanting corn and N application on competitive relationships in 2014 and 2015 seasons.

Treatment	Land Equivalent Ratio (LER)			LEC	Aggressivity (A)		Competitive ratio		
	L o orange	L c corn	LER		A orange	A corn	CR orange	CR corn	CR
	2014 season								
Solid Tree	1	1	1	1					
Solid corn	1	1	1	1					
A system + N1	0.652	0.340	0.992	0.22	+0.315	-0.315	0.99	0.72	1.71
A system + N2	0.739	0.391	1.130	0.29	+0.342	-0.342	0.97	0.73	1.70
A system + N3	0.833	0.430	1.263	0.36	+0.414	-0.414	1.00	0.71	1.71
A system + N4	0.871	0.504	1.375	0.44	+0.302	-0.302	0.89	0.80	1.69
Mean of syst. A	0.774	0.416	1.19	0.33	+0.343	-0.343	0.96	0.74	1.70
	2015 season								
Solid Tree	1	1	1	1					
Solid corn	1	1	1	1					
A system + N1	0.664	0.395	1.058	0.26	+0.205	-0.205	0.87	0.82	1.69
A system + N2	0.740	0.422	1.161	0.31	+0.272	-0.272	0.90	0.79	1.69
A system + N3	0.847	0.454	1.301	0.38	+0.378	-0.378	0.96	0.74	1.70
A system + N4	0.912	0.513	1.425	0.47	+0.351	-0.351	0.92	0.78	1.69
Mean of syst. A	0.791	0.446	1.237	0.36	+0.301	-0.301	0.91	0.78	1.69

A systems interplanting corn with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for corn crop.
Mean of syst. A = mean average of interplanting corn with orange trees.

Table 6: Impact of interplanting corn and N application on cereal units and economic return in 2014 and 2015 seasons.

Treatment	Yield ton fed^{-1}		Total cereal units (CUs)/ fed^{-1}	Total return L.E fed^{-1}		Total return of intercropping system L.E fed^{-1}	MAI L.E fed^{-1}
	Yield orange	Yield corn		orange fruits	corn		
	2014 season						
Solid Tree	6.588	-	16.47	19599	-	19599	-
Solid corn	-	3.1523	37.92	-	7711	7711	-
A system + N1	4.298	1.072	24.67	12786	2697	15483	-118
A system + N2	4.867	1.233	27.77	14478	3094	17572	2020
A system + N3	5.490	1.354	30.73	16333	3375	19707	3879
A system + N4	5.739	1.589	33.94	17073	3924	20997	5729
Mean of syst. A	5.099	1.312	29.28	15168	3273	18440	2878
	2015 season						
Solid Tree	6.683	-	16.71	21053	-	21053	-
Solid corn	-	3.211	36.93	-	7965	7965	-
A system + N1	4.435	1.267	25.66	13970	3205	17175	944
A system + N2	4.945	1.354	27.93	15575	3413	18988	2640
A system + N3	5.658	1.459	30.92	17822	3667	21489	4970
A system + N4	6.097	1.648	34.20	19206	4126	23332	6964
Mean of syst. A	5.284	1.432	29.68	16643	3603	20246	3880

Mean of syst. A = mean average of interplanting corn with orange trees.
**100 kg of (orange fruit = 0.25 unit, corn = 1 unit and straw corn =0.15 unit).*
**Farm gate prices of main and by products for L.E per ton were orange fruit (2975 & 3150), grain corn (2262 & 2300) straw corn (136) in 2014 & 2015 seasons, respectively.*

The second experiment (B):

Impact of interplanting soybean with orange trees and N application on:

B1: Soil NPK content:

Soil content of available NPK was remarkably greater in pure stand of soybean than under intercropped with Washington navel orange in both seasons as shown in Table (7). On the other hand, intercropping soybean (as legume crops) with orange trees increased orange soil content of available NPK (mg kg^{-1}) comparative to solid orange trees. Available N content enhance in soybean/orange orchards by increasing nitrogen fertilization. However, available P and K soil content of intercropping orange orchards was inconsistently increasing by increasing nitrogen fertilization. These results may be attributed to the role of soybean in fixing atmospheric N as well as pH reduction which increase the availability of other elements. The results of this study were in harmony with the findings of other workers Yan *et al.,* (1996); Eskandari *et al.,* (2009) and Zhou *et al.,* (2009). Opposite results were reported by Srivastava *et al.,* (2007). They indicated that phosphorus and potassium concentration in the orchard soil were depleted due to growing of leguminous crops.

Table 7: Impact of interplanting soybean and N application on orange soil content of NPK available (mg kg^{-1}) after harvesting soybean in 2014 and 2015 seasons.

Treatment	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}
	2014 season			2015 season		
Solid Tree	48.97	16.29	483.39	53.50	17.22	486.53
Solid soybean	62.14	25.13	564.21	79.21	23.48	521.28
B system + N1	49.50	19.55	551.98	53.90	22.16	502.98
B system + N2	51.20	16.33	538.91	56.00	19.48	496.65
B system + N3	57.90	18. 84	506.25	65.10	21.17	533.39
B system + N4	59.10	19.73	542.18	66.90	23.65	520.77
LSD at 5%	5.17	3.08	60.42	4.13	6.25	43.66

B systems interplanting soybean with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for soybean crop.

B2: Weeds prevalence in Washington navel orange orchards:

Results in Table (8) indicate that intercropping soybean with orange orchards significantly diminished fresh and dry weight of grassy, broad leaved and total weeds under any N fertilization levels fed^{-1} relative to orange pure stand. Total fresh and dry weeds weight in soybean/orange orchards were decreased by 74.62, 72.83, 58.96 and 58.26% over than pure stand of orange orchards, in both seasons, respectively. Increasing N levels up to 75% fed^{-1} (N4) significantly depressed weight of total fresh and dry weeds compared with unfertilized treatments (N1) by 43.31, 45.87, 44.28, and 47.88% under orange orchard intercropping, respectively, in the two seasons. These results are in agreement with those reported by Gold *et al.,* (2006); Linares *et al.,* (2008) and Bauri *et al.,* (2010).

B3: Fruit characters, yield and quality of Washington navel orange trees:

Interplanting soybean with orange at 50 and 75% N levels significantly enhanced fruit physical characters (weight, dimensions and size), juice volume and fruit chemical quality (TSS%, acidity % and vitamin C content) compared to pure stand of orange trees**.** While, orange trees without applied N fertilizer fed^{-1} were significantly reduced previous characters, except acidity % far below level of significance, in both seasons as shown in Table (9). No. of fruit, fruit weight $tree^{-1}$ and fruit yield fed^{-1} of orange orchards intercropped with soybean at 50 or 75% N levels were equal to or exceeding solid orange orchards.

Yield fed^{-1} of intercropping orange trees increases at 75% N level fed^{-1} over than solid trees by 5.46 and 6.04% in 2014 &2015 seasons, respectively. These results expected since interplanting soybean at high N levels increased available NPK soil content of orange orchards that in turn enhanced fruit physical characters and yield. These results were in accordance with those reported by Srivastava *et al.* (2007); Shirgure (2012) and Hnamte *et al.,* (2013). They found that citrus orchards with legumes as intercrop (soybean and chickpea), produced significantly higher fruit yield as compared to orchards without intercrops. Three years study indicated that N, P, and K application significantly promoted citrus growth in young stage and improved both fruit yield and quality (Wei *et al.,* 2004 and Morgan *et al.,* 2009).

Table 8: Impact of interplanting soybean and N application on fresh and dry weight of grassy, broad leaved and total weeds (g m^{-2}) under orange orchards in 2014 and 2015 seasons.

Treatment	Fresh grassy weeds (g m^{-2})	Fresh broad weeds (g m^{-2})	Total fresh weeds (g m^{-2})	Dry grassy weeds (g m^{-2})	Dry broad weeds (g m^{-2})	Total dry Weeds (g m^{-2})
	2014 season					
Solid Tree	584.21	942.32	1526.50	165.71	215.91	381.62
Solid soybean	102.33	149.42	251.75	27.92	34.12	62.04
B system + N1	304.33	235.33	539.66	88.86	57.17	146.03
B system + N2	236.00	190.00	426.00	66.09	48.12	114.21
B system + N3	189.00	89.33	278.33	51.73	23.80	75.53
B system + N4	222.92	83.00	305.92	58.65	20.40	79.05
LSD at 5%	69.97	58.65	102.02	35.84	29.00	50.41
	2015 season					
Solid Tree	277.84	521.34	799.18	82.40	113.77	196.18
Solid soybean	169.27	95.10	264.37	42.89	21.47	64.36
B system + N1	264.33	199.25	463.58	69.98	45.80	115.79
B system + N2	161.00	176.30	337.30	44.80	42.10	86.90
B system + N3	139.44	113.33	252.77	37.33	27.21	64.54
B system + N4	112.33	145.99	258.32	29.46	30.89	60.35
LSD at 5%	46.35	49.92	50.28	25.14	23.11	33.33

B systems interplanting soybean with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for soybean crop.

Table 9: Impact of interplanting soybean and N fertilization on fruit yield, fruit physical and chemical properties of Washington navel orange in 2014and 2015 seasons.

Treatment	Fruit weight (g)	Fruit dimensions diameter of		Fruit Size (cm^3)	Juice volume (cm^3)	TSS (%)	Acidity (%)	Vitam in C mg/100ml	No. of fruit/ Tree (No)	Fruit weight /Tree (Kg)	Fruit yield /Fed (Ton)
		Polar (cm)	Equ. (cm)								
	2014 season										
Solid Tree	251.22	8.17	7.54	248.33	95.63	12.17	0.970	52.33	156.09	39.21	6.588
B system+N1	230.72	7.52	7.27	195.83	77.50	10.17	1.033	44.83	155.44	35.86	6.025
B system+N2	246.83	7.82	7.42	206.67	82.50	11.00	0.967	52.31	158.34	39.08	6.566
B system+N3	251.00	8.33	7.75	251.67	99.17	12.33	0.883	53.66	158.08	39.68	6.666
B system+N4	259.50	8.23	7.95	254.17	100.0	12.50	0.833	57.05	159.37	41.36	6.948
LSD at 5%	5.93	0.45	0.56	15.47	8.21	0.40	0.276	3.60	3.89	0.77	0.252
	2015 season										
Solid Tree	253.14	8.75	8.14	251.33	92.67	11.50	1.000	53.56	157.31	39.82	6.690
B system+N1	232.22	7.41	7.32	193.33	71.67	9.33	1.023	49.33	156.21	36.28	6.094
B system+N2	248.22	8.10	7.78	226.00	80.00	10.33	0.966	52.34	156.10	38.75	6.510
B system+N3	252.89	8.77	7.99	248.33	93.33	10.67	0.875	55.42	158.95	40.20	6.753
B system+N4	261.33	9.11	8.26	256.67	98.80	11.33	0.800	58.00	161.58	42.23	7.094
LSD at 5%	9.13	0.46	0.66	9.20	8.77	0.97	0.256	2.48	3.39	1.06	0.178

B systems interplanting soybean with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for soybean crop.

B4: Growth, yield components, yield and seed protein content% of soybean as well as nitrogen use efficiency (NUE):

Data listed in Table (10) markedly show that crop growth rate (CGR), light intensity %, plant height, No. of branches and pods $plant^{-1}$, seed weight $plant^{-1}$ and 100 seed weight were significantly decreased by interplanting soybean with orange trees in both seasons. The decreases in CGR at different growth periods and light intensity % on middle of the soybean plants were 19.50, 24.13 and 26.79 and 21.77% compared with soybean alone as average of both seasons. Whereas, increasing N levels from zero (N1) up to 75 % (N4) level fed^{-1}, of the recommended fertilizer level of soybean, significantly enhancing all studied traits in both seasons, except light intensity %. The highest values of these traits were achieved at 75% N (N4) followed by 50% levels fed^{-1} (N3), the opposite trend was true for light intensity %. Differences between four N levels were significant during both seasons with some exceptions, particularly in some cases when comparing N levels of either (N3 & N4) or (N1&N2). These results may be due to growing soybean under citrus orchards maximizing both below and above ground interspecific competition and reduced the interception solar radiation by these crops and crop growth rate. Similar results are agreed with those reported by Eskandari and Ghanbari (2009). Puntel (2012) found that leaf area index and light interception of solar radiation were reduced by a decrease in individual leaf area, when zero or 90 kg N ha^{-1} were applied compared to 225 kg N ha^{-1}.

Seed and straw yields as well as protein content % were significantly affected by cropping systems and N fertilizer applications (Table, 10). Soybean intercropping significantly decreased seed yield over than monoculture by 70.17, 66.23, 61.28 and 56.72% under different levels of N fertilizer application zero, 25, 50 and 75% as average of the both seasons, respectively. Similarly, straw yield and protein content% of soybean seeds reduced resulting of interplanting soybean with orange orchards at different N levels, these results were true in the two seasons of study. Under polyculture, increasing N levels form zero up to 75% fed^{-1} significantly improved soybean seed yields by 47.64 and 42.56%. Similarly, straw yield and protein content % of soybean significantly increased due to increasing N levels up to 75% in the two seasons. It is worth to noting that differences between 50 and 75% of N levels application did not reached level of significances. These results attributed to sever interspecific competition between soybean and orange trees resulting in reduction in CGR and light intensity% consequently reduced seed and straw yields as well seed protein % but increasing N level reduced negative effect of intercropping. Similar results were announced with those reported by Eskandari and Ghanbari (2009); Puntel (2012) and Amujoyegbe and Elemo (2013).

Data presented in Table (10) clearly show that applying N fertilizer at 75 % recorded the highest values of NUE (4.04 and 3.24), respectively, in in the two tested seasons. While, the lowest values of NUE were achieved at 25% N level. The high efficiency of fertilization in the first season may be due to lower soil content of N in the first season compared to the second season. There was a decreasing pattern in nitrogen use efficiency values with increasing fertilizer rates, indicating that crop production could be sustained with lower fertilizer applications (De Juan *et al.,* 2005).

Table 10: Impact of interplanting soybean and N application on growth, yield and its components of soybean grown under orange orchards in 2014 and 2015 seasons.

Trait / Treatment	Crop growth rate (CGR) (g/ week) at 45-60 days	60-75 days	75-90 days	light intensity (%)	Plant height (cm)	Branches / plant (No)	Pods plant (No)	100 seed weight (g)	Seed yield fed^{-1} (ton)	Straw yield fed^{-1} (ton)	Seed protein content %	N use efficiency kg S /kg N
	2014 season											
Solid soybean	3.97	5.21	5.73	10.04	115.60	3.46	36.54	16.73	1.250	2.074	25.13	-
A system + N1	2.94	3.05	4.00	9.71	82.25	1.94	28.15	14.00	0.382	1.377	22.38	-
A system + N2	3.13	3.92	4.33	8.06	88.32	2.01	29.51	14.89	0.438	1.473	22.51	3.73
A system + N3	3.09	4.20	4.52	7.15	97.31	2.13	29.68	15.00	0.503	1.489	23.99	4.03
A system + N4	3.61	3.95	4.75	6.52	110.00	2.77	30.45	15.36	0.564	1.594	24.15	4.04
LSD at 5%	0.37	0.41	0.26	1.03	5.23	0.27	2.01	1.00	0.083	0.130	0.38	0.26
	2015 season											
Solid soybean	4.67	5.39	6.56	9.64	118.12	3. 48	37.33	16.89	1.338	2.137	25.66	-
A system + N1	3.45	3.57	4.35	8.83	85.43	2.10	28.97	14.21	0.390	1.578	22.41	-
A system + N2	3.52	4.34	4.67	7.96	96.45	2.24	29.68	15.30	0.436	1.636	23.16	1.73
A system + N3	3.96	4.49	4.71	7.09	102.80	2.60	30.27	15.75	0.499	1.648	23.87	2.97
A system + N4	4.12	4.65	4.66	6.26	110.72	2.98	31.55	16.08	0.556	1.670	24.33	3.24
LSD at 5%	0.30	0.32	0.35	1.35	7.43	0.32	0.75	1.21	0.095	0.117	0.40	0.30

B systems interplanting soybean with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for soybean crop.

B5: Competitive relationships:

Data in Table (11) markedly indicate that all interplanting treatments increased land equivalent ratio (LER) over than 1.0, and had land equivalent coefficient (LEC) over than 0.25. This means yield advantages and land use efficiency were detected by growing both crops together and vice versa.

Increasing N levels from 0 up to 75% enhanced LER and LEC by 23.11 and 67.20 % as average of two seasons. The values of L_o of orange tree were higher than those L_s of soybean. Aggressivity (A) values of orange tree were consistently positive and soybean consistently negative in 2014 and 2015 seasons. That is meaning that orange tree was dominant while soybean was dominated. Where, orange trees had competitive ratio (CR) higher than soybean when they were intercropped together, that indicating higher competitiveness of orange than the other component. The best values of aggressivity (0.744 and 0.839) were recorded with soybean/orange intercropping at 75% N level fed^{-1}. Also, competitive ratio (CR) of intercrops decreased with increasing N levels up to 75% fed^{-1} in both seasons. Similar results were obtained by Ahmed- Nagwa *et al.,* (2014). They found that intercropping clover, fenugreek and field bean with sewy date palms increased LER over than 1.0 and had competitive ratio higher than that in the three intercrops when they were intercropped together**.**

Table 11: Impact of interplanting soybean and N application on competitive relationships in 2014 and 2015 seasons.

Treatment	Land Equivalent Ratio (LER)			LEC	Aggressivity (A)		Competitive ratio		
	L o orange	L s soybean	LER		A orange	A soybean	CR orange	CR soybean	CR
	2014 season								
Solid Tree	1	1	1	1					
Solid soybean	1	1	1	1					
B system + N1	0.915	0.306	1.220	0.28	+0.849	-0.849	1.54	0.46	2.00
B system + N2	0.997	0.350	1.347	0.35	+0.884	-0.884	1.47	0.49	1.95
B system + N3	1.012	0.402	1.414	0.41	+0.786	-0.786	1.30	0.55	1.84
B system + N4	1.055	0.451	1.506	0.48	+0.744	-0.744	1.20	0.59	1.79
Mean of syst. B	0.994	0.377	1.372	0.38	+0.816	-0.816	1.38	0.52	1.90
	2015 season								
Solid Tree	1	1	1	1					
Solid soybean	1	1	1	1					
B system + N1	0.911	0.291	1.202	0.27	+0.877	-0.877	1.61	0.44	2.05
B system + N2	0.973	0.326	1.299	0.32	+0.902	-0.902	1.54	0.46	2.00
B system + N3	1.009	0.373	1.382	0.38	+0.852	-0.852	1.39	0.51	1.90
B system + N4	1.060	0.416	1.476	0.44	+0.839	-0.839	1.31	0.54	1.86
Mean of syst. B	0.988	0.351	1.340	0.350	+0.867	-0.867	1.46	0.49	1.95

B systems interplanting soybean with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for soybean crop.
Mean of syst B = mean average of interplanting soybean with orange trees.

B6: Cereal units (CUs), total return and monetary advantages index (MAI):

Orange polyculture system improved CUs fed^{-1} by (27.16 and 27.67 units) compared with orange alone (16.47 and 16.73 units), respectively, in the two seasons. Raising N application from zero up to 75% significantly increased cereal unit fed^{-1} by about 23.03 and 20.85%, respectively, in both seasons as shown in Table (12). The results are in agreement with those reported by El-Maihy-Amira (2011).

Soybean/orange trees intercropping systems significantly increased total return and MAI (L.E. fed^{-1}) over solid culture of orange trees or soybean in both seasons as shown in Table (12). The increases in total return due to intercropping at 75% N level were 19.16 and 18.78 % over than orang pure stand. Increasing N levels from zero up to 75% of soybean markedly increased MAI from (L.E. 3572 and 3571) to (L.E. 7845 and 8072) in two the seasons, respectively. Intercropping legume crop improve fruit yield, consequently increased total return and MAI. The results are in harmony with those obtained by Osman *et al.,* (2011); Shoeib (2012); Hnamte *et al.,* (2013) and Ahmed- Nagwa *et al.,* (2014).

Table 12: Impact of interplanting soybean and N application on cereal units and economic return in 2014 and 2015 seasons.

Treatment	Yield ton fed^{-1}		Total cereal units (CUs)/fed^{-1}	Total return L.E fed^{-1}		Total return of intercropping system L.E fed^{-1}	MAI L.E fed^{-1}
	Yield orange	Yield soybean		Orange fruits	Soybean		
	2014 season						
Solid Tree	6.588	-	16.47	19599	-	19599	-
Solid soybean	-	1.250	23.94	-	5691	5691	-
B system + N1	6.025	0.382	24.23	17924	1869	19793	3572
B system + N2	6.566	0.438	26.66	19534	2128	21662	5581
B system + N3	6.666	0.503	27.93	19831	2406	22237	6514
B system + N4	6.948	0.564	29.81	20670	2684	23354	7845
Mean of syst. B	6.551	0.472	27.16	19490	2272	21762	5878
	2015 season						
Solid Tree	6.690	-	16.73	21074	-	21074	-
Solid soybean	-	1.338	25.41	-	6158	6158	-
B system + N1	6.094	0.390	25.03	19197	2015	21212	3571
B system + N2	6.510	0.436	26.90	20505	2144	22649	5212
B system + N3	6.753	0.499	28.49	21272	2420	23692	6553
B system + N4	7.094	0.556	30.25	22346	2686	25032	8072
Mean of syst. B	6.613	0.470	27.67	20830	2316	23146	5852

Mean of syst B = mean average of interplanting soybean with orange trees.
**100 kg of (orange fruit = 0.25 unit, soybean =1.5 units and straw soybean = 0.25 unit).*
**Farm gate prices of main and byproducts L.E. per ton were orange fruit (2975 & 3150), seeds soybean (4261& 4336) and straw soybean (176 & 172) in 2014 & 2015 seasons, respectively.*

The third experiment (C):

Impact of interplanting cowpea with orange trees and N application on:

C1: Soil NPK content:

Available NPK (mg kg^{-1}) content in cowpea/orange intercropping were markedly increased than solid orange orchards in both seasons as shown in Table (13). On the other hand, intercropping orange trees with cowpea depleted soil content of available NPK comparative to solid cowpea. Increasing N fertilization improved crop growth rate of cowpea so enhance available N content in intercropping orange orchards. Similarly, available P soil content of intercropping orange orchards was significantly increased with high nitrogen fertilization levels. While available K was inconsistently increasing resulting in increased N fertilization level. These results could be due to the role of cowpea (as legume crop) in fixing N as well as pH reduction which increase the availability of other elements. The results of this study were in harmony with the findings of other workers Yan *et al.,* (1996); Eskandari *et al.,* (2009) and Zhou *et al.,* (2009). Bado *et al.,* (2013) reported similar observations on soybean, groundnut, and cowpea had N fertility equivalencies of 30, 35, and 42 kg N ha^{-1}.

Table 13: Impact of interplanting cowpea and N application on orange soil content of NPK available (mg kg^{-1}) after harvesting cowpea in 2014 and 2015seasons.

Treatment	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}
	2014 season			2015 season		
Solid Tree	48.75	16.54	493.19	53.00	17.92	470.32
Solid cowpea	89.40	24.66	581.37	86.60	23.24	460.52
C system + N1	54.60	16.13	535.65	63.00	21.01	516.05
C system + N2	63.00	18.39	525.85	66.50	20.02	525.85
C system + N3	70.00	20.20	512.78	74.70	22.72	540.93
C system + N4	76.10	21.47	564.81	79.80	23.03	513.00
LSD at 5%	8.19	2.80	53.84	5.20	5.24	65.29

C systems interplanting cowpea with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50and 75% of the recommended fertilizer level for cowpea crop.

C2: Weeds prevalence in Washington navel orange orchards:

Fresh and dry weights of grassy, broad leaved and total weeds in orange orchards significantly controlled due to interplanting cowpea at any N fertilization levels fed^{-1} relative to orange pure stand (Table, 14). Decreases in total fresh and dry weeds weight were 79.61, 80.79, 77.29 and 75.73% over than pure stand of orange orchards, in both seasons, respectively. Increasing N levels up to 75% fed^{-1} (N4) significantly decreased weight of total fresh and dry weeds compared with unfertilized treatments (N1) from 398.67 and 111.09 to 249.33 and 67.54 g m^{-2} in 2014 season and from175.00 and 66.58 to 146.67 and 34.88 g m^{-2} in 2015 season under intercropping orange orchard, respectively. Cowpea is a cleaner crop attributed to cutting the forage crop twice leading to a greatest reduction in the spread of weeds. These results are in agreement with those reported by Gold *et al.,* (2006); Linares *et al.,* (2008) and Bauri *et al.*, (2010).

Table 14: Impact of interplanting cowpea and N application on fresh and dry weights of grassy, broad leaved and total weeds (g m^{-2}) under orange orchards in 2014 and 2015seasons

Treatment	Fresh grassy weeds (g m^{-2})	Fresh broad weeds (g m^{-2})	Total fresh weeds (g m^{-2})	Dry grassy Weeds (g m^{-2})	Dry broad weeds (g m^{-2})	Total dry Weeds (g m^{-2})
	2014 season					
Solid Tree	526.33	925.57	1451.9	148.48	214.19	362.68
Solid cowpea	124.00	43.33	167.33	34.62	10.60	45.23
C system + N1	258.67	140.00	398.67	74.06	37. 38	111.09
C system + N2	182.67	83.33	266.00	56.06	23.47	79.53
C system + N3	179.17	91.17	270.33	47.14	24.21	71.35
C system + N4	151.33	98.00	249.33	43.81	23.72	67.54
LSD at 5%	43.09	38.80	49.77	18.03	12.54	25.78
	2015 season					
Solid Tree	357.6	465.19	822.79	100.62	104.27	204.89
Solid cowpea	68.33	30.00	86.67	19.31	7.14	26.45
C system + N1	146.70	85.00	175.00	43.17	23.48	66.58
C system + N2	125.00	55.00	166.67	39.67	16.26	55.99
C system + N3	106.68	50.83	143.75	27.03	14.41	41.44
C system + N4	86.67	33.33	146.67	25.96	8.86	34.88
LSD at 5%	30.55	9.16	25.71	7.37	14.12	25.61

C systems interplanting cowpea with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50and 75% of the recommended fertilizer level for cowpea crop.

C3: Yield and quality fruits of Washington navel orange tree:

Data listed in Table (15) markedly indicated that polyculture system under different N application levels were significantly affected on fruit characters, quality and fruit yield fed^{-1} in both seasons. Interplanting cowpea with orange orchards at different N level improved average of fruit weight, fruit dimensions and size, juice volume and chemical fruit quality (TSS%, acidity % and vitamin C content) compared with pure stand of orange orchards, except unfertilized treatment. The favorable effect of cowpea on these traits was resulting in high soil content of nutrients. Similarly, increased N fertilization levels enhanced these traits over than unfertilized plots.

Number and weight of fruit $tree^{-1}$ as well as fruit yield fed^{-1} were significantly increased when interplanting cowpea with orange trees than solid orange trees, especially, at 50 and 75 % N level fed^{-1}. Fruit yield fed^{-1} at 75% N level increased by 9.62 and 10.14% over than solid trees in 2014 and 2015 seasons, respectively. The good effects of cowpea as legume crops and N fertilization on fruit number and weight $tree^{-1}$ were reflected to achieve yield advantage. The results are quit expected and are in good agreement with those reported by Wei *et al.,* (2004); Olanyan and Fagbayide (2007); Srivastava *et al.,* (2007); Abdel-Aziz *et al.,* (2008); Morgan *et al.,* (2009); Mousavi and Eskandari (2011); Shirgure (2012); Aboutalebi (2013) Ijaz *et al.,* (2014); Ahmed-Nagwa *et al.,* (2014) and Gebru (2015).

Table 15: Impact of interplanting cowpea and N fertilization on fruit yield, fruit physical and chemical properties of Washington navel orange in 2014and 2015 seasons.

Treatment	Fruit weight (g)	Fruit dimensions diameter of Polar (cm)	Fruit dimensions diameter of Equ. (cm)	Fruit Size (cm^3)	Juice volume (cm^3)	TSS (%)	Acidity (%)	Vitamin C mg/100ml	No. of fruit/ Tree (No)	Fruit weight /Tree (Kg)	Fruit yield /Fed (Ton)
	2014 season										
Solid Tree	251.44	8.08	7.73	249.00	91.83	12.17	0.967	52.11	156.30	39.30	6.602
C system+N1	236.94	7.62	7.28	198.33	85.83	10.83	0.977	49.91	159.55	37.80	6.351
C system+N2	249.05	7.90	7.67	220.83	90.00	11.83	0.867	53.26	160.14	39.88	6.700
C system+N3	256.55	8.50	8.07	258.33	92.50	12.00	0.847	58.64	162.48	41.68	7.003
C system+N4	263.02	8.32	8.00	261.67	102.5	12.50	0.817	60.23	163.77	43.07	7.237
LSD at 5%	7.71	0.48	0.13	15.65	5.23	1.11	0.130	2.99	5.50	0.97	0.164
	2015 season										
Solid Tree	253.00	8.28	8.56	251.00	92.33	11.60	0.997	52.79	157.24	39.78	6.683
C system+N1	239.00	7.38	7.80	205.00	81.67	9.67	1.004	52.00	159.16	38.04	6.391
C system+N2	254.09	8.44	7.99	226.67	90.00	10.00	0.989	58.60	161.02	40.91	6.873
C system+N3	255.67	8.33	8.01	256.67	92.50	11.70	0.950	60.45	164.71	42.11	7.075
C system+N4	265.50	9.50	8.91	257.33	99.50	11.70	0.814	64.33	165.02	43.81	7.361
LSD at 5%	6.37	0.36	0.73	5.64	4.70	0.82	0.145	3.64	2.25	0.60	0.138

C systems interplanting cowpea with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50and 75% of the recommended fertilizer level for cowpea crop.

C4: Growth, yield components, fresh and dry forage of cowpea as well as nitrogen use efficiency (NUE):

Data in Table (16) clearly show that crop growth rate (CGR), light intensity %, plant height, No. of branches plant^{-1}, leaf/steam ratio were significantly decreased due to interplanting cowpea under orang orchards compared to solid cowpea in both seasons. These results were expected since shading effect of orange tree lead to reduction in solar radiation penetration within cowpea canopy and sever competition of orange trees significantly decreased crop growth rate. Which negative effect on CGR and light intensity% reflect on growth and development of cowpea. These negative effects reduced by increasing N fertilization levels and increased these traits in two seasons. Differences between four N levels were significant during both seasons with some exceptions, particularly in some cases when comparing N levels of either (N3 & N4) or (N1&N2). Abd El-Lateef *et al.,* (2015) confirmed that light interception showed reductions along the intercropped cowpea canopies at the different heights of measuring, compared with the solid recommended cultures.

Moreover, data in the same Table, show that fresh and dry forage yields were significantly affected by cropping systems and N fertilizer applications in both seasons. Intercropping cowpea with orange orchard significantly decreased fresh and dry forage yields by 57.23, 52.33, 47.33and 44.37% for fresh yield and were 59.30, 53.44, 47.49 and 44.49% for dry yield as average of two cuts under different levels of N fertilizer application (zero, 25, 50 and 75%) as average of the both seasons, respectively. Under polyculture, increasing N levels form zero up to 75% fed^{-1}, of N levels of recommendation of cowpea significantly improved fresh and dry forage yields for two cuts by 30.08 and 36.41%, respectively, as average of 2014 & 2015 seasons. It is worth to notice that differences between 50 and 75% of N levels application did not reached level of significances of these traits. Cowpea mean yields in the intercropped systems were generally lower than in the sole crop. This could be due to higher inter-specific competition for available resources such as nutrients, soil moisture and root spaces between intercrops (Onasanya *et al.,* 2009; Puntel, 2012 and Amujoyegbe and Elemo, 2013).

Also, data in Table (16) clearly show that applying N fertilizer at 50 % in the first season or 25% in the second seasons recorded the highest values of NUE (5.22 and 6.87), as average of two cuts of cowpea forage. Differences between 25 and 50% level failed to reach level of significance in both seasons. While, the lowest values of NUE were achieved with cowpea at 75% N level. These results may be attributed to cowpea as legume crops enriching soil orchards with available N therefore, NUE decreased with increasing of N fertilization. There was a decreasing pattern in nitrogen use efficiency values with increasing fertilizer rates, indicating that crop production could be sustained with lower fertilizer applications (De Juan *et al.,* 2005 and Bado *et al.,* 2013).

Table 16: Impact of interplanting cowpea and N application on growth, yield and its components of cowpea grown under orange orchards in 2014 and 2015 seasons.

Trait / Treatment	Crop growth rate (CGR) (g/ week) 42-49 2days	49-56 days	Light intensity (%)	Plant height (cm) 1 cut	2 cut	Branches/ plant (No) 1 cut	2 cut	Leaf/stem ratio plant^{-1} 1 cut	2 cut
	2014 season								
Solid cowpea	6.64	5.37	7.53	104.7	97.67	4.20	2.55	0.73	0.64
A system + N1	3.02	2.68	6.81	84.73	77.00	1.42	1.12	0.50	0.43
A system + N2	3.67	3.39	6.37	89.40	83.33	2.40	1.50	0.59	0.48
A system + N3	5.41	4.48	6.45	99.20	95.33	2.74	1.71	0.67	0.54
A system + N4	6.17	4.93	5.89	110.54	99.23	3.27	2.05	0.71	0.59
LSD at 5%	0.94	0.85	N.S	9.09	5.92	0.82	0.40	0.07	0.09
	2015 season								
Solid cowpea	7.23	6.81	7.76	110.67	98.89	4.59	2.03	0.72	0.69
A system + N1	3.65	3.12	7.34	90.67	81.67	2.37	2.03	0.55	0.47
A system + N2	4.78	4.04	7.03	105.67	87.00	3.47	2.04	0.64	0.57
A system + N3	5.74	5.51	6.36	101.00	97.00	4.08	2.70	0.71	0.62
A system + N4	6.97	6.13	5.94	115.21	105.19	4.36	2.90	0.73	0.67
LSD at 5%	1.30	0.95	1.43	7.10	6.51	0.73	0.53	0.06	0.08

Trait / Treatment	Fresh forage yield/ fed (ton) 1 cut	2 cut	Dry forage yield/fed (ton) 1 cut	2 cut	NUE (kg dry matter /kg N) 1 cut	2 cut	NUE of tow cuts
	2014 season						
Solid cowpea	9.839	3.969	2.023	0.848	-	-	-
A system + N1	4.402	1.479	0.871	0.307	-	-	-
A system + N2	4.780	1.683	0.967	0.355	6.40	3.20	4.80
A system + N3	5.133	1.973	1.058	0.433	6.23	4.20	5.22
A system + N4	5.388	2.258	1.116	0.484	5.44	3.93	4.69
LSD at 5%	0.280	0.289	0.035	0.057	1.11	0.24	0.88
	2015 season						
Solid cowpea	10.230	4.352	2.139	0.956	-	-	-
A system + N1	4.274	1.986	0.845	0.405	-	-	-
A system + N2	4.955	2.116	0.990	0.466	9.67	4.06	6.87
A system + N3	5.169	2.678	1.079	0.563	7.80	5.27	6.54
A system + N4	5.458	2.689	1.122	0.590	6.16	4.11	5.14
LSD at 5%	0.368	0.343	0.098	0.025	0.59	0.22	0.91

C systems interplanting cowpea with orange trees and treated with different nitrogen fertilization levels
N1, N2, N3 and N4 equal zero, 25, 50and 75% of the recommended fertilizer level for cowpea crop.

C5: Competitive relationships:

The results in Table (17) indicate that land equivalent ratio (LER) and land equivalent coefficient (LEC) values were significantly affected by cropping systems and N fertilization levels in both seasons. Interplanting cowpea with orange orchards under all different levels of N application increased LER and LEC over than 1.0 and 0.25. This means that interplanting cowpea with orange orchards achieve yield advantages and increased land use efficiency. The highest values for LER and LEC (1.655 and 0.61)were observed when interplanting cowpea with orange trees at 75% N level, while the lowest LER and LEC values (1.387 and 0.41) were detected when interplanting cowpea at zero% N level in 2014 and 2015 seasons, respectively. Aggressivity (A) values of orange tree were consistently positive and cowpea consistently negative in 2014 and 2015 seasons as shown in Table (17), that is meaning that orange tree was dominant while cowpea were dominated. Orange trees had competitive ratio (CR) than that in cowpea crops and CR values for orange trees were higher than cowpea. Similar results were reported by Ahmed- Nagwa *et al.,* (2014) and Gebru, (2015).

Table 17: Impact of interplanting cowpea and N application on competitive relationships in 2014 and 2015 seasons.

Treatment	Land Equivalent Ratio (LER)			LEC	Aggressivity (A)		Competitive ratio		
	L o orange	L c cowpea	LER		A orange	A cowpea	CR orange	CR cowpea	CR
	2014 season								
Solid Tree	1	1	1	1					
Solid cowpea	1	1	1	1					
C system + N1	0.962	0.426	1.388	0.41	+0.644	-0.644	1.16	0.61	1.77
C system + N2	1.015	0.468	1.483	0.48	+0.635	-0.635	1.12	0.64	1.75
C system + N3	1.061	0.515	1.575	0.55	+0.603	-0.603	1.06	0.67	1.73
C system + N4	1.096	0.554	1.650	0.61	+0.571	-0.571	1.02	0.70	1.72
Mean of syst. C	1.033	0.491	1.524	0.51	+0.614	-0.614	1.09	0.65	1.74
	2015 season								
Solid Tree	1	1	1	1					
Solid cowpea	1	1	1	1					
C system + N1	0.956	0.429	1.385	0.41	+0.626	-0.626	1.15	0.62	1.77
C system + N2	1.028	0.485	1.513	0.50	+0.619	-0.619	1.09	0.65	1.74
C system + N3	1.059	0.538	1.597	0.57	+0.544	-0.544	1.01	0.70	1.72
C system + N4	1.101	0.559	1.660	0.62	+0.569	-0.569	1.02	0.70	1.72
Mean of syst. C	1.036	0.503	1.539	0.52	+0.589	-0.589	1.07	0.67	1.74

C systems interplanting cowpea with orange trees and treated with different nitrogen fertilization levels.
N1, N2, N3 and N4 equal zero, 25, 50 and 75% of the recommended fertilizer level for cowpea crop.
Mean of syst. C = mean average of interplanting cowpea with orange trees.

C6: Cereal units (CUs), total income and monetary advantages index:

Interplanting cowpea with orange trees increased total cereal units fed^{-1} by 60.08 and 64.99 % over than solid orange trees in the two seasons, respectively. The increases in total cereal units fed^{-1} were 19.49 and 20.49% by increasing N fertilization level from zero up to 75% in both seasons as shown in Table (18). Similar results were reported by El-Maihy- Amira (2011).

Table 18: Impact of interplanting cowpea and N application on cereal units and economic return in 2014 and 2015 seasons.

Treatment	Yield ton fed^{-1}		Total cereal units (CUs) /fed^{-1}	Total return L.E fed^{-1}		Total return of intercropping system L.E fed^{-1}	MAI L.E fed^{-1}
	Yield orange	Yield cowpea		orange fruits	cowpea		
	2014 season						
Solid Tree	6.602	-	16.51	19642	-	19642	-
Solid cowpea	-	13.81	19.33	-	3245	3245	-
C system + N1	6.351	5.881	24.01	18894	1499	20393	5699
C system + N2	6.7	6.463	25.7	19933	1637	21570	7024
C system + N3	7.003	7.106	27.35	20834	1787	22621	8261
C system + N4	7.237	7.646	28.69	21529	1915	23444	9234
Mean of syst. C	6.823	6.774	26.43	20298	1710	22007	7554
	2015 season						
Solid Tree	6.683	-	16.71	21053	-	21053	-
Solid cowpea	-	14.582	20.41	-	3427	3427	-
C system + N1	6.391	6.26	24.74	20130	1590	21720	6043
C system + N2	6.873	7.071	27.08	21651	1780	23431	7948
C system + N3	7.075	7.847	28.67	22285	1960	24245	9061
C system + N4	7.361	8.147	29.81	23186	2140	25326	10070
Mean of syst. C	6.925	7.331	27.57	21813	1868	23681	8281

Mean of syst. C = mean average of interplanting cowpea with orange trees.
**100 kg of (orange fruit = 0.25 unit and cowpea = 0.14 unit).*
**Farm gate prices of main and byproducts for L.E per ton were orange fruit (2975 & 3150) and cowpea fresh forage (235) in 2014 & 2015 seasons, respectively.*

Data in Table (18) reveale that all intercropping treatments significantly improved total return and MAI (L.E. fed^{-1}) over than orange tree or cowpea in solid culture of both seasons. Total return increased by 19.36 and 20.30 % comparative to solid orange at 75% N level, while increased N level from zero up to 75% raising MAI values by 62.03 and 66.64% in both seasons, respectively. This result could be attributed to cowpea its ability to fix atmospheric N and improved fruit yield of orange, consequently increased total return and MAI. The results are in agreement with those obtained by Osman *et al.,* (2011); Shoeib (2012); Hnamte *et al.,* (2013) and Ahmed- Nagwa *et al.,* (2014).

Conclusion

Growing three intercrops (corn, soybean and cowpea) under orange orchards improved orange soil content of NPK, reduced the spread of weeds and increased land use efficiency, CUs and total return as well as MAI fed^{-1} over than orange alone. Cowpea has a pride position among all intercrops in the study, followed by soybean. Intercropping legume crops at 50 and/or 75% N level under orange orchards increased fruit yield fed^{-1} and improve fruit quality. Growing corn with orange trees it need for further study to determine the optimum quantity of N fertilizer to minimize the adversely effect of intercropping on the orange trees.

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