

**“Impact of weed management practices on soil health indicators in a mango orchard with and without intercropping.”**

**THESIS**

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**Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur**

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***By***

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## VITA

*The author of this thesis was born on 1<sup>st</sup> July 1986 in Shahdol, Madhya Pradesh. He passed his Intermediate from Raghuraj Government Higher Secondary School Dist- Shahdol in the year 2003.*

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## CERTIFICATE - I

This is to certify that the thesis entitled, **“Impact of weed management practices on soil health indicators in a mango orchard with and without intercropping”** submitted in partial fulfilment of the requirement of degree of **MASTER OF SCIENCE in AGRICULTURE (Soil Science and Agricultural Chemistry)** for the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mohammad Rasid Khan** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded *etc.*) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

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## CERTIFICATE-II

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## CHAPTER - I

### INTRODUCTION

Soil health is the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health.

The concept of soil health and soil quality has consistently evolved with an increase in the understanding of soils and soil quality attributes. Soil quality cannot be measured directly, but soil properties that are sensitive to changes in management can be used as indicator. The soil health approach is better applied when specific goals are defined for a desired outcome from a set of decisions.

Farmers and researchers need readily available technical tools and information for assessing and enhancing soil quality that can be easily integrated into their operations.

The quantitative approach for assessing soil quality is well suited for trained professionals who can collect samples, conduct tests, interpret results, and make recommendations for management changes that will lead to improved soil quality. Several authors have proposed sets of soil quality indicators(Doran and Parkin, 1994; Sarrantonio *et al.*, 1996; Karlen *et al.*, 1998 ) A common feature of the proposed indicator sets is that they all include some combination of physical, chemical and biological soil properties, suggesting that for a soil to function effectively, all three components must be addressed. Assessing each of the chosen indicators is completed with a quantitative measurement, made either in the field or laboratory.

Weeds constitute a serious and continuing limitation to crop production in all agricultural systems. Weeds are competitive and adaptable to all the adverse environments. It has been estimated that in general weeds cause 5% loss to agricultural production in most developed countries, 10% loss in less developed countries and 25% loss in least developed countries. Of the total annual loss of

agricultural produce from various pests in India, weeds accounts for 45%, Insects 30%, diseases 20% and others 5%. Weed Management is essential for good quality and quantity of food. A crop may or may not be affected by insects or diseases under some situations but weeds will always be there where there is a crop. Weed is defined as the plants where they are not desired. Weeds compete with crop plants for sunlight, water and nutrients and thus become threat to the cultivation of any crop. Several methods of weed control, viz manual, mechanical, cultural and chemical methods are practiced in field condition, among this the chemical method is the cheapest. However, due to increased environmental awareness, the use of herbicides has become a great concern, now a days and it has become imperative to study the impact of herbicides on soil health.

Keeping in view the importance of weed management practices on soil health indicators, the current investigation was undertaken with following objectives:

**Objectives:**

1. To study the impact of cultural, chemical and mechanical weed management practices in a mango orchard on different soil health indicators i.e. physical, chemical and biological.
2. To study the impact of herbicides on nodulation in pea grown as intercrop in a mango orchard.

## CHAPTER –II

### REVIEW OF LITERATURE

A brief review of work carried out so far in relation to the impact of weed management practices on soil physico-chemical and biological properties has been presented in this chapter.

Wander *et al.*,(1994) Practised a 10 year comparison of organically and conventionally managed fields that showed higher levels of carbon and nitrogen accumulation in the organically managed soils. Cover cropped soils had organic matter with a high C/N ratio, which is indicative of high organic matter. Turnover rates, retention of soil organic matter in chemically stabilized forms, showed retention of the nitrogen by the soil. Conversely the conventionally managed soil had the smallest point of soil organic matter and lowest levels of biological activity.

Horning and Bunemann (1995) conducted an experiment to evaluate the effect of soil management, irrigation and fertigation in an IP apple orchard on soil nitrate content and on tree mineral nutrition. Five strip treatment were used : (1) chemical weed control; (2) cultural weed control; (3) ground cover with ground ivy (*Glechoma hederacea*); (4) ground cover with various grasses; and (5) ground cover with clover (*Trifolium repens*). Nitrate content in the top 90 cm of soil was determined throughout the season. Soil nitrate was more affected by strip treatment than by N application method, although fertigation gave a higher soil nitrate content than broadcast fertilizer application. Soil nitrate was highest with strip treatments (1), (2) and (5) and decreased with increasing distance from the fertigation nozzle, yet increased with increasing distance from the irrigation nozzle with broadcast application.

Mantsev (1995) studied effect of different systems of maintaining the inter-row strips of a cherry orchard on the physical and biological properties of the soil, to compare three management systems: (1) bare soil, kept loosened and weed-free (control); (2) complete sward, consisting of a mixture of annual and perennial

grassed; and (3) green manure crops sown in alternate - rows changing the inter-row strips each year. Soil density, soil structure and activity of microorganisms were monitored for two years. The results showed that systems (2) and (3) reduced the soil density and improved its structure and microorganism activity as compared to system (1).

Sharma *et al.*, (1995) conducted an experiment to evaluate the effect of graded levels of N (0, 200 and 400 g/tree) coupled with weed management practices (a weedy control, atrazine at 4.0 kg/ ha, oxfluorfen at 0.3 kg/ ha, diuron at 4.0 kg/ ha, grass mulch (10 cm thick) and black polythene mulch (1000-gauge) on  $\text{NH}_4$  and  $\text{NO}_3\text{-N}$  production in peach orchard soil . The production of  $\text{NH}_4$  and  $\text{NO}_3\text{-N}$  increased with increasing levels of N, and maximum concentration was recorded up to 60 days and declined afterwards. Weed control significantly improved  $\text{NH}_4$  and  $\text{NO}_3\text{-N}$  level .Diuron application followed by grass mulch proved to be the best treatments for stimulating the production of  $\text{NH}_4$  and  $\text{NO}_3\text{-N}$ . The combination of 400g N with diuron led to maximum stimulation. Weed control methods did not show any phytotoxic effects on peach plants.

Mantinger *et al.*, (1996) conducted an experiment on different floor management systems in apple orchards. Fifteen different systems of orchard floor management involving herbicides, cover crops, mulches and tillage were compared.. Weed infestation became a problem after the first 5 year when cover crops or bark mulches were used. Tillage was a better option but was costly. Herbicide treatment was the most economic option but needed to be combined with cultural practices in order to reduce environmental impacts.

Babeanu *et al.*,(1997) Conducted an experiment in 1994-1995 in a plum orchard at the Baneasa farm (Romania) to determine the effect of different soil managements on the biological properties of soil. Treatment included worked field (V1), field treated with herbicide Roundup (V2), field cultivated with perennial grasses (V<sub>3</sub>), and natural grasses (V<sub>4</sub>). Soils at V1and V2 were plowed In the autumn, while the grasses at V3 and V<sub>4</sub> were mowed twice a year and drown out from the plantation. The enzymatic potential, the vital potential, and

synthetic indicators of the soil fertility, were analysed. Results show that soils with grasses have higher values of enzymatic potential. The respiratory potential and soil fertility indicators were highest under  $V_2$ .

Bielinska and Lipecki (1998) conducted an experiment to determine the effect of the method of soil maintenance in an apple orchard on the possibility of limiting soil chemical and biological degradation. Trees of apple were given 0 or 432 kg NPK fertilizer/ha and orchard floor maintained with herbicide (simazine), (diquat) and (glyphosate) or grass strips. Higher amounts of total carbon were found in the soil under grass than in that under the herbicide strip. The soil under grass, irrespective of fertilizer application, was less acid and its nitrate nitrogen content was lower than under the herbicide strip. Enzymatic activity was much lower in the soil under herbicide strips than under grass. It is concluded that grass strips inhibit soil degradation processes in orchards.

Drinkwater et al., (1998) analysed nitrogen and carbon losses from organic and conventionally managed field over 15 years. Conventionally managed fields had less N immobilization & 50% more nitrate leaching than the organic plots. The organically managed field also had greater water holding capacity, water infiltration and less soil erosion than conventionally managed fields.

Singh and Wright (1999) performed two pot experiments to study the effects of three pre-emergence herbicides (terbutryn/ terbutylazine, trietazine/ simazine and prometryn ) and a post emergence herbicide (bentazone) on nodulation, symbiotic nitrogen fixation, growth and yield of pea. All pre-emergence herbicides decreased nodulation, total nitrogenase activity, net photosynthesis, leaf area, root and shoot dry weight. The results suggested that the decreased growth of herbicide- treated plants was due to direct effects of the herbicides on peas and not due to indirect effects of the herbicides on rhizobia.

Andrews *et al.*, (2001) conducted an experiment to assess the long term effect of organic, conventional and integrated apple production systems on soil/plant mineral relations and fruit quality. Organic soil management practices

have included additions of manure and bark mulches, woven polypropylene fabric, and mechanical control for weed control. Conventional soil management practices included synthetic fertilizers and herbicides for weed control. The Integrated treatment utilized a combination of organic and conventional practices. The result indicated that the total top soil N was significantly higher in the organic and Integrated systems compared to the conventional systems, although nitrate N was lowest in the organic system.

Khokhar *et al.*, (2001) conducted an experiment to determine the effect of integrated orchard floor management systems on the physico-chemical and microbiological properties of almond orchard soil in Solan, Himachal Pradesh India. The pH and EC of orchard soil were not significantly influenced by the different orchard floor management practices. However, the use of herbicides and organic mulches slightly reduced soil pH whereas EC was increased compared with unweeded control. The highest increase in organic carbon content was recorded with grass mulch followed by glyphosate treatment. Integrated use of mulches and herbicides increased available N, P, K, Ca and Mg contents of the soil.

Merrington *et al.*, (2002) assessed the impact of copper- based fungicides on soil microbial function in an avocado orchard. Copper residues in surface soil of an established avocado orchard were significantly greater than a nearby reference site under natural vegetation. Data suggested that the Cu residues are responsible for significant reductions in biomass carbon (C<sub>mic</sub>) even though the orchard soils had similar or elevated levels of total organic carbon.

Draghi *et al.*, (2003) studied the response of orchard soil from north Patagonia, Argentina under two different conditions grass covered and uncovered to different traffic intensities. The parameters measured were bulk density, resistance to penetration and structural porosity. Traffic had a significant influence on macropores reduction. The maximum traffic intensity condition on uncovered soil decreased significantly the structural porosity index in all the layers considered. The application of a reduced traffic intensity did not avoid

over-compaction Grass cover in the area between rows decreased soil susceptibility to traffic- induced compaction.

Kumar and Chauhan (2003) conducted a field experiment during 1994-2001 at Bajaura, Himachal Pradesh, India to study the effect of orchard soil management practices (clean cultivation, herbicide, green-manuring, intercropping, mulching+ herbicide) and 4 levels of nitrogen (200, 400 and 600 and 400 g, half applied as Calcium ammonium nitrate and half as farmyard manure per plant) on 6- year – old plum. The highest leaf N, Cu, and Zn were observed with the herbicide treatment. The P and K were the highest with mulching + herbicide. The lowest N, P and K were observed under intercropping with soybean. The highest available soil N was observed under green-manuring with cowpea (*Vigna unguiculata*), available P, and K, exchangeable Ca, and Mg with mulching + herbicide. Increasing the N level increased the available soil N, P, Fe and Zn content.

Singh *et al.*, (2005) studied the effect of paclobutrazol doses on nutritional and microbiological properties of mango (*Mangifera indica*) orchard soils. Paclobutrazol was applied as soil drench in mango orchards. The application of paclobutrazol at 8.0 g a.i./ha for 2 consecutive years increased the soil pH from 7.0 to 7.55. The soil organic carbon content decreased significantly under all treatments. P, K and Ca levels in soil increased at lower rates of paclobutrazol but decreased at higher rates (6 and 8 g a.i./ ha). Sodium, Zn, Cu, Mn and Fe levels remained more or less the same. The microbial population increased in soil treated with paclobutrazol except at higher rates.

Trintinalio *et al.*, (2005) conducted an experiment to evaluate the effect of different soil management systems in peach palm inter rows on chemical and physical properties of a dystrophic red latosol. Treatments included : weed control with herbicides (HB); soil covered with sugarcane biogases (SB); alternate green manures with velvet bean and oats cropping as inter- row crops (VA); inter- row manual weed control (MC); inter- row slashing mechanical weed control (slashing) (MWC); and inter- row cropping of pigeon pea (PG). Soil bulk

density, soil porosity, carbon contents, sum of bases and CEC did not differ among treatments. Values of pH,  $\text{Al}^{+3}$ ,  $\text{Ca}^{+2}$ ,  $\text{Mg}^{+2}$ ,  $\text{K}^{+}$  were influenced by treatments with a positive increment in those treatments with specific weed control (HB and MWC), While for P, the treatments HB, MC and MWC stood out positively.

Singh and Wright (2006) studied the effect of one pre-emergence herbicide (terbutryn/terbuthylazine) and one post-emergence herbicide (bentazone), along with unweeded and hand- weeded controls, on weed density, and on the nodulation, nitrogenase activity, nitrogen content, growth and yield of pea in Bangor, Gwynedd, UK. The herbicides reduced the number of nodules, dry weight of nodules, nitrogenase activity, shoot dry weight, nitrogen content of straw and seeds, and seed yield, with the effects generally being greater at higher rate of application.

Vogeler *et al.*,(2006) conducted an experiment to determine the of wheel traffic and two different management practices on soil compaction and its consequences on physical and chemical soil properties. The parameters were used penetration resistance, water infiltration, bulk density, macroporosity, chemical mobility, air permeability, and soil strength in a conventional apple orchard with bare rows and an organic apple orchard with grassed rows in New Zealand in may 2005. The result indicated that compaction was greater in the wheel tracks under both management methods. Compaction in the wheel track was higher under organic than conventional management. Organic management resulted in a higher macroporosity in both the row and wheel- track than conventional management. Infiltration rate was significantly greater within the row of the organic orchard (0.06m/h) compared with the row of the conventional orchard (0.02m/h), and compare with the wheel tracks (0.01m/h). Apart from this physical and chemical soil characteristics were in a better condition compared with the conventional orchard.

Yang *et al.*,(2007) Studied the effect of weed management practices on soil biological and fertility properties. Three weed management practices were

chemical control plus tillage (herbicide), tillage alone (plowed) and mowing plus tillage (mowed). No significant differences in microbial biomass carbon (MBC), soil organic matter (SOM) or total nitrogen (TN) were observed among the three practices in the first year of the experiment. In the second and third year of the experiment, soil MBC, SOM, and TN were significantly higher with mowed and plowed than with herbicide. Soil MBC, SOM and TN were higher with mowed than plowed treatment only in the third year. Mycorrhizal fungal spore and phosphorus- solubilizing microbial (PSM) activity tended to increase during the experiment in all treatments. Highest mycorrhizal fungal spore and PSM activity were found with mowing throughout the experiment.

Deurer *et al.*,(2008) studied a new method to quantify the impact of soil carbon management on biophysical soil properties .As a significant factor for soil quality, the soil carbon (C) management in the topsoil of an integrated and organic apple orchard was selected and compared and analyzed the impact of the soil C management on biological (microbial biomass C, basal respiration, dehydrogenase activity, respiratory quotient) and physical (aggregate stability, amount of plant- available water, conductive mean pore diameter near water saturation) soil properties. The results indicated that the impact of soil C management was better correlated with soil microbial than with the physical properties with respect to environmental soil functions that are sensitive to the decrease in microbial activity or aggregate stability.

Moreno *et al.*, (2009) conducted an experiment to determine the long-term effect of soil management on biological indicators of soil quality. In this study, four long term approaches to olive orchard management, categorized by the presence/absence of two main factors- cover crops and chemical weed control- were evaluated using biological indicators of soil quality. The result indicated that covered soil exhibited greater bacterial biomass and diversity, as well as higher microbial functional diversity than non covered soils. When non covered soil was considered, the lowest value of microbial activity and diversity were found when weeds were controlled with chemical methods.

Ramos *et al.*, (2010) examined the effect of different cover crop managements and frequent tillage on soil physical, chemical and biological properties in almond orchards in SE Spain. Wet aggregate stability, total organic carbon, total nitrogen, carbon: nitrogen ratio, phosphatase and beta- glucosidase activities increased with cover crops, whereas the soil- water content declined, especially for the grain-straw treatment. This study suggests that cover crops in semiarid environments improve soil quality compared to frequently tilled management, by increasing the organic matter content, improving the chemical and physical fertility of the soil, and enhancing the soil biological activity.

Fountas *et al.*, (2011) evaluated the effect on physico chemical property of soil and yield of orchards tree in 2007 and 2008. Weed control was practiced during the previous 3 years using post emergence herbicides under no- tillage over about 2/3 of the field and over the remaining 1/3 by mechanical weeding using a rotary cultivator. The soil properties measured were penetration resistance, soil texture, organic matter, pH, P, NO<sub>3</sub>-N, K, Mg, Zn, Mn, Fe, B and Ca contents. The results indicated considerable spatial variation in yield and soil properties. The soil organic matter content was about 22 % greater and the penetration resistance about 26% less in the areas under no-tillage .The mean pH increased from 5.9 to 7.0 as a result of lime application in the areas with pH below 6.5.

Dian ming *et al.*, (2011) conducted an experiment to evaluate soil fertility indices of citrus orchard land along topographic gradients in the three gorges area of china. This study was conducted to compare the effects of 10 years of various management practices citrus intercropped with white clover (WC), citrus mulched with straw (SM), citrus intercropped with contour hedgerows (CH), citrus orchard land with impermeable membrane (IM) and citrus intercropped with wheat (*Triticum aestivum*) and peanut (*Arachis hypogaea*) (WP). Results showed that the soil organic carbon, total and available nitrogen, available potassium, and water- stable aggregate (> 0.25 mm) contents at the 0-5 cm depth were higher for the WC and SM treatments than the CM treatment. There was also spatial variation in soil fertility along slopes of the WC and SM

treatments. The soil total and available nitrogen, phosphorus, and potassium and water- stable aggregate (0.25 mm) contents at both the 0-5 and 5-20 cm depths were higher for the CH and IM treatments than the CM treatment.

Peck *et al.*,(2011) studied soil properties change during the transition to integrated and organic apple production. Chemical composition, physical properties and biological properties were measured at 0-6 and 6-12 cm soil depths over four years. The results indicated that the mulch with infrequent herbicide application provided effective weed control in integrated fruit production and increased soil organic matter, pH, nutrient availability, microbial biomass C and microbial respiration. Mechanical cultivation and chicken manure compost were used for organic fruit production, which increased soil porosity, decreased aggregate stability and increased potentially mineralizable and total Inorganic N. For most measurements, minimal treatment differences were found at 6-12 cm soil depth. Soil quality did not improve as much in organic fruit production as in the integrated fruit production system soil.

## **CHAPTER – III**

### **MATERIAL AND METHODS**

Methodology used during the course of investigation has been described in this chapter. The relevant data were evolved in the Soil Science section, Directorate of Weed Science Research, (DWSR) & Department of Soil Science and Agricultural Chemistry (College of Agriculture, JNKVV) Jabalpur.

The present study was conducted in two stages i.e. collection of soil samples from the experimental mango orchard, DWSR farm and their analyses for different soil quality parameters.

#### **3.1 General Description of the area**

##### **3.1.1 Location and Climate**

Jabalpur is situated between 22<sup>0</sup>29' and 24<sup>0</sup>48' N latitude and 78<sup>0</sup>21' and 80<sup>0</sup>58' E longitude with an altitude of 393 metres above mean sea level. .It has a semi arid and sub tropical climate with a characteristics feature of dry summer and cold winter. In winter season i.e. from November to February, the temperature ranges from 7.02<sup>0</sup>C to 28.55<sup>0</sup>C and the relative humidity varies from 32.5 - 93 per cent. Dry and warm weather usually prevails during the month of March to June. The temperature in the month of May attains temperature as high as 42.06<sup>0</sup>C. Monsoon season extends from mid June to mid September. The temperature during this period varies between 23.45<sup>0</sup>C and 41.6<sup>0</sup>C and the relative humidity ranges between 22 to 89.25 per cent. The total annual rainfall was found to range from 1200 to 1500 mm. The meteorological data from June 2011 to May 2012 are given in the table 3.1.

**Table 3.1 Meteorological data from May 2011 to April 2012**

**(Collected from Meteorological observatory, College of Agricultural Engineering, JNKVV Jabalpur.)**

Meteorological weeks	Temperature (°C)		Relative humidity (%)		Wind velocity	Sun Shine (hrs/day)	Rainfall (mm)	Rainy days (Nos)
	Max.	Min.	Max.	Min.				
27	32.8	23.8	86	61	9.7	4.9	15.2	2
28	32.0	23.5	92	71	6.8	3.1	46.4	3
29	30.3	22.8	93	83	9.4	2.5	429.1	6
30	29.9	22.7	90	70	7.3	9.4	119.2	3
31	31.1	23.6	92	82	5.3	3.9	140.0	5
32	28.7	22.7	93	85	7.8	1.5	118.5	6
33	29.8	22.7	92	78	4.5	4.0	57.6	3
34	30.9	22.9	93	70	6.1	6.3	14.6	3
35	31.5	22.8	96	71	5.0	5.8	150.6	7
36	29.5	22.6	94	80	7.2	1.2	221.6	4
37	29.9	22.4	93	73	4.6	3.9	92.2	3
38	30.8	21.9	93	67	5.5	5.1	41.0	4
39	31.3	20.8	86	36	4.5	6.9	0.0	0
40	32.2	18.6	90	47	5.3	9.0	5.2	1
41	32.4	19.1	92	43	4.7	8.3	0	0
42	32.6	18.8	89	31	4.0	9.3	0	0
43	31.5	13.9	87	30	2.8	8.9	0	0
							1451.2	50

### 3.1.2 Experimental site

The experiment was conducted at DWSR research farm. The soil of the experimental site is vertisol and is commonly known as black cotton soil with sandy-clay loam texture. The soil is of swell- shrink nature and shows wide and deep cracks during summer months.

### 3.1.3 Treatment

Mango was planted in the site during the year at 9 m plant to plant and 9 m row to row distance. The each plant received 5kg FYM on dry weight basis and 100g DAP once in a year in their basins. The floor of the orchard was demarcated into plots of 8m x 17m dimension in such a way that two plants lied in each plot. The plots were subjected to 8 treatments of weed control measures by following randomized block design (RBD) with 4 replications. The detail of the treatments are shown in table 3.2.

**Table 3.2 Weed control measures followed in the mango orchard**

Treatments	season		
	Kharif	rabi	Summer
<b>T1</b>	Cowpea intercrop	Pea intercrop	Cowpea intercrop
<b>T2</b>	Black gram intercrop	Pea intercrop	Moongbean intercrop
<b>T3</b>	T1+Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season	T1+Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season	T1+Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season
<b>T4</b>	T2+ Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season	T2+ Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season	T2+ Pendimethalin 1kg/ha or fluchloralin 1 kg/ha in a season
<b>T5</b>	Metribuzin 0.5 kg/ha in a season	Metribuzin 0.5 kg/ha in a season	Metribuzin 0.5 kg/ha in a season
<b>T6</b>	Glyphosate 2 kg/ha once in a season	Glyphosate 2 kg/ha once in a season	Glyphosate 2 kg/ha once in a season
<b>T7</b>	Mechanical weeding using rotavator (Twice) one in the beginning of the season and once after 30 days	Mechanical weeding using rotavator (Twice) one in the beginning of the season and once after 30 days	Mechanical weeding using rotavator (Twice) one in the beginning of the season and once after 30 days
<b>T8</b>	Permanent weedy plot	Permanent weedy plot	Permanent weedy plot

The intercrops (T1-T4) were grown by following conventional tillage operation (rotavator) and received application of P at the rate of 46 kg/ha and N 18 kg/ha through DAP. The plots under the treatment T3&T4 received pre-plant incorporation (PPI) of fluchoralin during all the three seasons of the first year of experiment (2008).Afterwards, these plots received pendimethalin as pre-emergence (PE) application in each season during the subsequent years.

### **3.1.4 Soil sampling**

The soil samples were collected from 0-15 cm depth of each plot after 1, 6 and 15 weeks of imposition of the Kharif treatments during 2011. The samples were dried, ground to pass through 2mm sieve and analysed for pH, EC, organic carbon, available mineral N, available P and available K. Similarly the samples were also collected after imposition of rabi treatments, and besides the above mentioned chemical parameters, the samples were analysed for microbial biomass carbon content. The observations on soil physical parameters, viz, BD, porosity, infiltration and penetration force, were recorded during January 2012.

## **3.2 Methods of Analysis**

Soil samples collected during kharif 2011-2012 were analysed for chemical properties and the samples collected during rabi2011-2012 were analysed for chemical, physical and biological properties. The scheme of detailed analyses is as follows:

### **3.2.1 Physical Properties**

#### **3.2.1.1 Bulk Density**

Soil samples were collected manually from the plots with the help of a high carbon steel core sampler of 4 cm diameter and 10 cm long. The samples were oven dried at 105°C and the bulk density was calculated on the oven dry weight basis (Black, 1965).

$$\text{Bulk Density (g cm}^{-3}\text{)} = \text{Oven dry soil weight (g)} / \text{Volume of soil (cm}^3\text{)}$$

### **3.2.1.2 Porosity**

The Porosity was calculated from the ratio of Bulk Density and Particle Density as suggested by Saha (2004).

$$\text{Porosity (\%)} = 1 - (\text{Bulk Density (g cm}^{-3}\text{)} / 2.65) \times 10$$

### **3.2.1.3 Infiltration rate**

Infiltration rate was measured in-situ as per method described by Bouwer (1986).

### **3.2.1.4 Penetration resistance**

Penetration resistance was measured in-situ using needle type penetrometer(dia of needle(0.02m) as described by Bradford(1986).

## **3.2.2 Chemical Properties**

### **3.2.2.1 Soil Reaction**

The pH was determined in 1: 2.5 soil- water suspensions using digital pH meter (Jackson, 1967).

### **3.2.2.2 Electrical Conductivity**

The electrical conductivity of the 1: 2.5 soil- water extract was measured using solu bridge (Jackson, 1967).

### **3.2.2.3 Organic Carbon**

The organic carbon was determined by rapid titration method as described by Walkley and Black (1934).

### **3.2.2.4 Available Soil mineral Nitrogen**

The soil mineral nitrogen was determined by extraction of exchangeable ammonium nitrate & nitrite nitrogen followed by steam distillation method as described by Keeney and Nelson (1982).

### 3.2.2.5 Available Soil Phosphorus

The available phosphorus was extracted by 0.5M NaHCO<sub>3</sub> solution adjusted to 8.5 pH and determination was done by Ascorbic Acid method as suggested by Miller and Keeney (1982).

### 3.2.2.6 Available soil Potassium

The procedure was based on extraction with 1N NH<sub>4</sub>OAc (pH 7.0) and K was determined by Flame Photometer (Muhr *et al.*, 1965).

## 3.2.3 Biological Properties

### 3.2.3.1 Microbial Biomass Carbon

The Microbial Biomass carbon was estimated by Chloroform Fumigation Extraction method (Brookes, *et al* 1985).

## Reagents

- (i) Distilled chloroform
- (ii) Conc. H<sub>2</sub>SO<sub>4</sub>
- (iii) 0.5M K<sub>2</sub>SO<sub>4</sub>: 43.563 g K<sub>2</sub>SO<sub>4</sub> was dissolved in distilled water and volume was made up to 500 ml.
- (iv) 0.2 N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>: 0.9808 g K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> was dissolved in 100 ml of distilled water, and volume was made up to 1000 ml.
- (v) Orthophosphoric acid
- (vi) 0.005 N Ferrous Ammonium Sulphate (FAS): 3.92 g of ferrous ammonium sulphate was dissolved in 1 liter distilled water and 15 ml conc. H<sub>2</sub>SO<sub>4</sub> was also added and then volume was made up to 2 L with distilled water.
- (vii) Diphenylamine indicator

## Procedure

1. Three sets of 10 g soil samples were weighed and one set of soil samples was kept for moisture determination.
2. Second set of soil samples was kept in 50 ml beakers for fumigation. Remaining one set was packed and kept in refrigerator for extraction next day.
3. Twenty ml of chloroform was taken in a separating funnel. It was washed two times with conc.  $\text{H}_2\text{SO}_4$  (with half of the volume of chloroform) and the acid (bottom phase) was discarded. It was washed twice with the same volume of distilled water similarly to make the chloroform free of ethanol and the bottom whitish phase was collected.
4. One set of samples was fumigated with ethanol free chloroform in a vacuum desiccator. The vacuum desiccator was attached to the vacuum pump and the air was evacuated until the chloroform boiled. Then the vacuum desiccator was stored in dark room over night.
5. Next day the vacuum was released and chloroform was removed from the desiccator.
6. Unfumigated soil samples were taken from refrigerator and thawed.
7. Transferred both the fumigated and unfumigated soils in 250 ml conical flasks. Added 25 ml of 0.5 M  $\text{K}_2\text{SO}_4$  and shaken for 30 minutes. After shaking filtered the suspension through Whatman No. 1 filter paper.
8. Ten ml of the filtrate was taken in 100 ml conical flask and 2 ml of  $\text{K}_2\text{Cr}_2\text{O}_7$  (0.2 N) and 10 ml of conc.  $\text{H}_2\text{SO}_4$  was added to it. The contents of the flask were allowed to cool for half an hour then 5 ml orthophosphoric acid was added along with 200 ml distilled water. Minimum two blanks were also run with 10 ml distilled water.

9. Two to 3 drops of diphenylamine indicator were added and the content was titrated against ferrous ammonium sulphate (0.005 N) to get a brick red end point.

**Calculation:**

$$\text{Microbial biomass carbon in soil } \mu\text{g g}^{-1} \text{ soil} = \frac{\text{Ext. } C_F - \text{Ext. } C_{UF}}{0.25}$$

Where,

Ext.  $C_F$  : Extractable fumigated carbon

Ext.  $C_{UF}$  : Extractable unfumigated carbon

$$\text{Where, Ext. } C_F \text{ or Ext. } C_{UF} = \frac{(B-T)}{B} \times 600 \times \frac{2}{10} \times \frac{25 + \text{wt. of moist soil} \times \%M/100}{\text{Wt. of dry soil}}$$

B= Blank value (ml)

T= Titre value (ml)

M= Moisture content of the wet soil (%)

**3.2.3.2 Nodulation**

**3.2.3.2.1 Number of nodules**

Observation on nodulation parameters were recorded at 45 & 65 days after sowing of pea during rabi 2011-12 by uprooting 3 plants/plot taking sufficient care to avoid any losses or damage of nodules. The rhizosphere soil was washed in the running water. After proper washing plant nodules were counted manually.

**3.2.3.2.2 Nodule dry matter**

After counting, the nodules were detached from the roots and were kept in small paper bags. Then the nodules were oven dried in hot air oven at 60<sup>0</sup>C for 3-4 days (till constant weight) to record nodule dry matter.

**3.2.3.3 Plant biomass**

**3.2.3.3.1 Plant dry biomass**

After nodulation studies the root portion of the plants was cut off, roots and shoots were dried in a hot air oven at 60<sup>0</sup>C for 10-15 days (till constant weight) to record the dried plant biomass.

## CHAPTER-IV

### RESULT

This chapter presents the results obtained during the investigations carried out in the field and laboratories under the following headings.

#### **4.1 Impact of cultural, chemical and mechanical weed management practices on soil physical properties in the mango orchard**

In order to evaluate the impact of cultural, chemical and mechanical weed management practices on soil physical health; the attributes, *viz.* bulk density and porosity of the soil, *in-situ* basic and cumulative infiltration, and penetration resistance in the plots under different weed control measures (floor management practices) in the mango orchard were determined during winter 2011-12. Standard procedures and precise equipments were used to determine these physical attributes. Results obtained are presented in the following sub heads.

##### **4.1.1 Impact on bulk density**

In general, the practice of intercropping ( $T_1$ ,  $T_2$ ,  $T_3$  and  $T_4$ ) in the mango orchard favored the soil to maintain its bulk density at significantly lower level, as compared to keeping the field permanently weedy ( $T_8$ ). The Bulk densities of the soils collected from the plots under different weed management practices in the mango orchard are presented in table 4.1. It is evident from the data that the highest bulk density was observed in permanently weedy plots ( $1.35\text{g/cm}^3$ ) followed by glyphosate ( $T_6$   $1.34\text{ g/cm}^3$ ) and metribuzin ( $T_5$   $1.29\text{ g/cm}^3$ ) treated plots. Lowest value ( $1.15\text{ g/cm}^3$ ) of bulk density was recorded in the treatment  $T_1$ , i.e. cowpea-pea-cowpea inter cropping without herbicide. It was statistically similar to the bulk density values as recorded in case of other intercropped ( $T_2$ ,  $T_3$  and  $T_4$ ) and mechanically weeded plots ( $T_7$ ).

##### **4.1.2 Impact on porosity**

The impact of different weed management practices on the porosity of floor soils of the mango orchard are presented in table 4.1. Reverse observation

was noticed in case of porosity vis-à-vis bulk density. Porosity was highest in cowpea-pea-cowpea intercropped plots (T<sub>1</sub>) and lowest in weedy check plots i.e.T<sub>8</sub>.

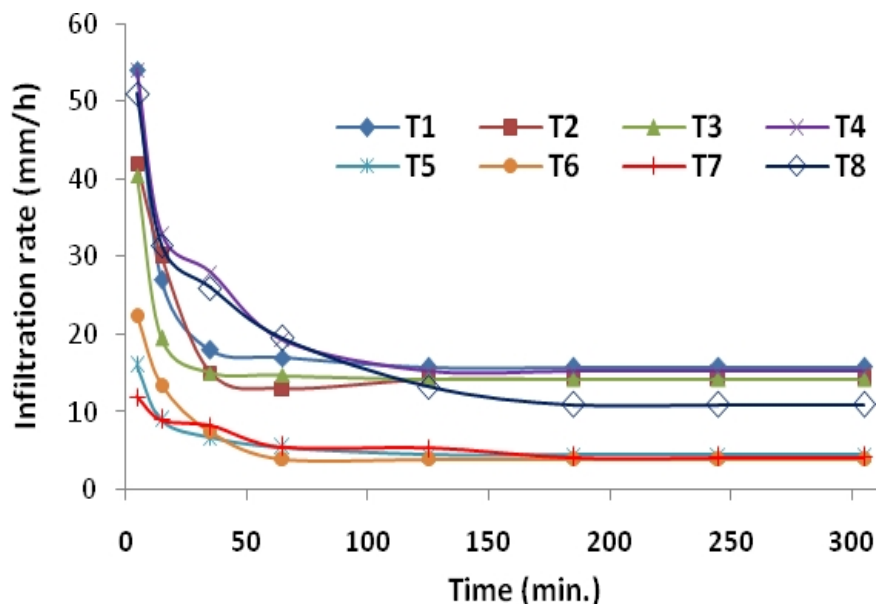
**Table 4.1: Impact of different weed management practices on soil Bulk density, porosity, infiltration and penetration force at 40 days after sowing in mango orchard**

Treatments	Penetration force, kg/cm <sup>2</sup>			Bulk density (g/cm <sup>3</sup> )	Porosity (%)	Basic IR (mm/h)
	0-5 cm depth	0-10 cm depth	0-15 cm depth			
T1: Cowpea-pea-cowpea	3.84	5.90	7.94	1.15	56.50	15.80
T2: Blackgram-Pea-Moongbean	3.63	5.65	7.98	1.19	55.20	14.30
T3:T1+ Pendimethalin/fluchloralin	3.80	6.04	8.12	1.22	54.10	14.30
T4: T2+ Pendimethalin/fluchloralin	3.75	5.91	7.85	1.17	55.90	15.30
T5: Metribuzin 0.5 kg in each season	3.66	6.56	8.23	1.29	51.40	4.50
T6: Glyphosate 2 kg in each season	3.51	6.79	8.49	1.34	49.60	4.00
T7: Mechanical (Rotavator) weeding	3.40	6.04	8.36	1.25	52.80	4.30
T8: Weedy check	4.68	6.46	8.43	1.35	49.10	11.00
<b>CD (0.05)</b>	<b>0.48</b>	<b>0.44</b>	<b>0.30</b>	<b>0.12</b>	<b>4.46</b>	<b>4.60</b>

#### 4.1.3 Impact on basic and cumulative Infiltration rate

Basic and cumulative Infiltration data were collected *in-situ* using double ring infiltrometer under various treatments. These data were processed and infiltration rate curves and cumulative infiltration curves for the treatments under different weed management practices in the mango orchard are presented in fig.4.1 and fig.4.2, respectively. The infiltration rate curves showed that the

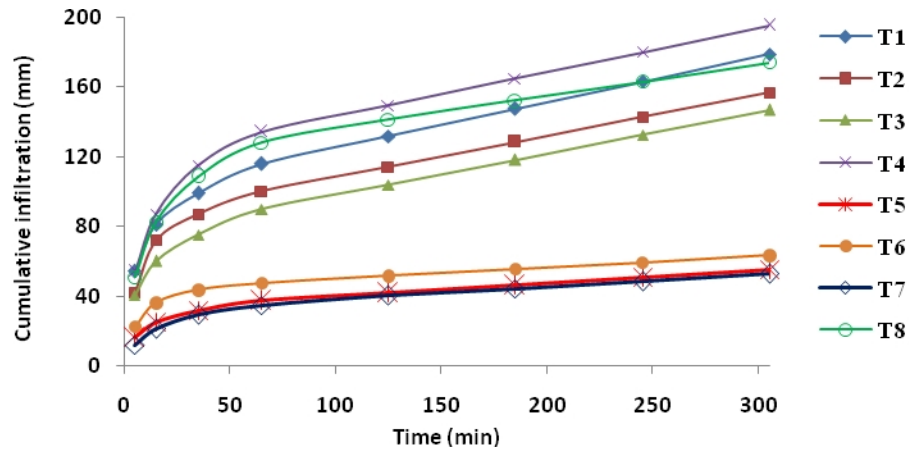
infiltration rate sharply declined with time from the start of the application of water in all the plots. The constant rate of infiltration, which is referred to as steady-infiltration rate or basic infiltration, approached roughly after 120 minutes. The basic infiltration rate as observed under different treatments is shown in table 4.1. Among the treatments, the highest infiltration rate was observed in T<sub>1</sub> (15.8 mm/h) followed by T<sub>4</sub> (15.3 mm/h), T<sub>2</sub> (14.3 mm/h), T<sub>3</sub> (14.3 mm/h) and T<sub>8</sub> (11.0 mm/h). The values of basic infiltration rate as observed in the intercropped plots (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>) were statistically similar to each other and were significantly higher than the values as recorded in case of sole chemical (T<sub>5</sub> and T<sub>6</sub>) and mechanical weeding (T<sub>7</sub>) treatments. The lowest value of basic infiltration rate was observed in glyphosate treated plots (4.0 mm/h) and it was statistically similar to metribuzin (T<sub>5</sub>) and rotavator (T<sub>7</sub>) treatments.



T<sub>1</sub>: Cowpea-pea-cowpea intercropping; T<sub>2</sub>: Blackgram-Pea-Moongbean intercropping; T<sub>3</sub>: T<sub>1</sub>+ Pendimethalin 1 kg per season; T<sub>4</sub>: T<sub>2</sub>+ Pendimethalin 1 kg per season; T<sub>5</sub>: Metribuzin 0.5 kg per season; T<sub>6</sub>: Glyphosate 2 kg per season; T<sub>7</sub>: Rotavator twice per season; T<sub>8</sub>: Weedy check

**Fig.4.1. Impact of weed management practices on in-situ infiltration curves.**

The cumulative curve as presented in fig 4.2 indicated that, the highest cumulative infiltration rate was observed in T<sub>4</sub> plot (195mm) followed by T<sub>1</sub> plot (179mm), T<sub>8</sub> plot (174mm), T<sub>2</sub> plot (157mm), T<sub>3</sub> plot (147mm), T<sub>6</sub> plot (64mm), T<sub>5</sub> plot (55mm), T<sub>7</sub> plot (53mm) respectively.



T<sub>1</sub>: Cowpea-pea-cowpea intercropping; T<sub>2</sub>: Blackgram-Pea-Moongbean intercropping; T<sub>3</sub>: T<sub>1</sub>+ Pendimethalin 1 kg per season; T<sub>4</sub>: T<sub>2</sub>+ Pendimethalin 1 kg per season; T<sub>5</sub>: Metribuzin 0.5 kg per season; T<sub>6</sub>: Glyphosate 2 kg per season; T<sub>7</sub>: Rotavator twice per season; T<sub>8</sub>: Weedy check

**Fig.4.2. impact of weed management practices on in-situ cumulative infiltration in mango orchard.**

#### 4.1.4 Impact on penetration force

Penetration force was measured with the help of needle type penetrometer at 0-5, 0-10 and 0-15 cm depth and at saturated moisture condition. The penetration force recorded various weed management practices are presented in table 4.1.

Generally, penetration force increased with increasing soil depth. Penetration force required for the 0-5 cm depth was highest (4.68 kg/cm<sup>2</sup>) in the weedy plots (T<sub>8</sub>), and it was significantly higher over rest of the treatments. The lowest penetration resistance value of 3.40 kg/cm<sup>2</sup> was recorded in mechanically weeded plots (T<sub>7</sub>); however, it was statistically similar to the penetration

resistance observed in the plots subjected to intercropping (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>) and sole chemical weed control measures (T<sub>5</sub>, T<sub>6</sub>).

The highest penetration force required for 0-10 cm depth was observed in glyphosate treated plots (6.79 kg/cm<sup>2</sup>), which was statistically similar to metribuzin treated (6.56 kg/cm<sup>2</sup>) and weedy check plots (6.46 kg/cm<sup>2</sup>). In rest of the treatments, i.e. intercropping and sole mechanical weeding, the penetration force needed for 0-10 cm depth ranged from 5.65 to 6.04 kg/cm<sup>2</sup>, these values were statistically similar to each other but significantly lower than that observed in weedy and sole herbicidal treatments.

As in the case of 0-10 cm depth, the highest penetration resistance for 0-15 cm depth was showed by glyphosate treated plots (8.49 kg/cm<sup>2</sup>), which was statistically similar to weedy check plots (8.43 kg/cm<sup>2</sup>), mechanically weeded plots (8.36 kg/cm<sup>2</sup>) and metribuzin treated plots (8.23 kg/cm<sup>2</sup>). Similar to 0-5 cm and 0-10 cm depths, the intercropping treatments did not vary among them and showed relatively lower penetration resistance for 0-15 cm depth compared to other treatments.

## **4.2 Impact of cultural, chemical and Mechanical weed management practices on soil chemical attributes in mango orchard**

In order to evaluate the Impact of cultural, chemical and mechanical weed management practices on soil chemical attributes, viz. soil reaction, electrical conductivity, organic carbon, soil mineral nitrogen, available phosphorus and available potassium were determined at initial, 40 days after sowing and at harvest for both *kharif* and *rabi* seasons. Results obtained are presented in following sub-heads.

### **4.2.1 Impact on soil reaction**

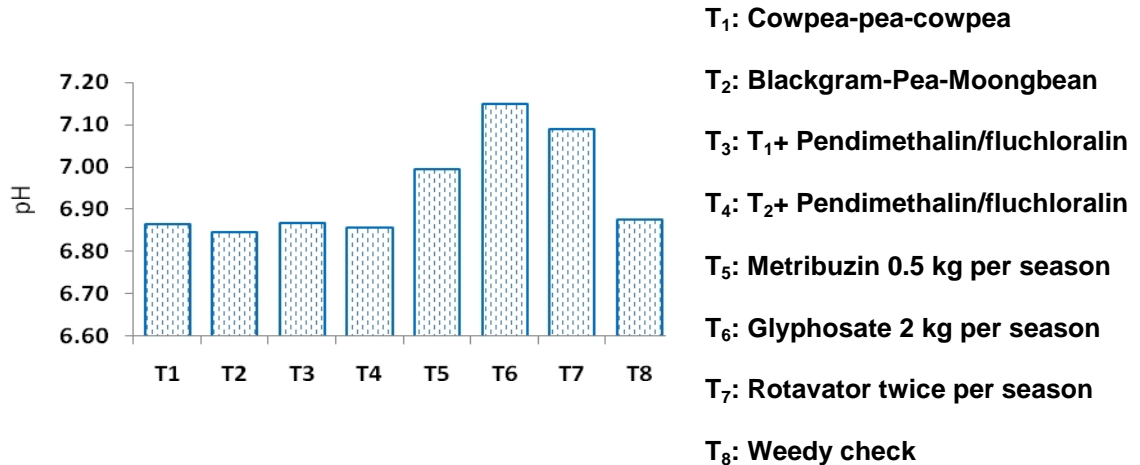
To study the impact of different weed management practices on soil reaction, soil samples were taken and analysed using the standard procedures. The data are presented in table 4.2.

The pH of the plots varied slightly with the sampling season. From the beginning of the *kharif* season the pH values showed a continuous decreasing trend with time and relatively lower values were recorded during mid-*kharif* to early *rabi* seasons, thereafter a reverse trend was noticed, i.e. it showed a gradual increasing trend and became similar to that as recorded at the beginning of *kharif* season.

**Table 4.2: Impact of different weed management practices on soil reaction (pH) in mango orchard**

Treatments	Cropping season					
	Kharif (2011)			Rabi(2011-12)		
	Date of soil sampling			Date of soil sampling		
	10 Jul	19 Aug	10 Oct	1 Dec	9Jan	6 Mar
T1: Cowpea-pea-cowpea	7.00	6.89	6.71	6.73	6.80	7.07
T2: Blackgram-Pea Moongbean	6.97	6.89	6.75	6.65	6.88	6.94
T3:T1+ Pendimethalin/fluchloralin	6.99	6.93	6.61	6.72	6.90	7.06
T4: T2+ Pendimethalin/fluchloralin	6.98	6.93	6.65	6.68	6.83	7.09
T5: Metribuzin 0.5 kg in each season	7.18	7.00	6.78	6.86	7.02	7.14
T6: Glyphosate 2 kg in each season	7.35	7.10	6.88	7.05	7.15	7.38
T7: Mechanical (Rotavator) weeding	7.23	7.06	6.99	6.92	7.09	7.25
T8: Weedy check	7.02	6.91	6.76	6.67	6.90	6.98
<b>CD(0.05)</b>	<b>0.28</b>	<b>0.16</b>	<b>0.18</b>	<b>0.21</b>	<b>0.22</b>	<b>0.21</b>

The data pooled across the sampling dates (Fig.4.3) showed that the sole chemical ( $T_5$ ,  $T_6$ ) and mechanical treatments ( $T_7$ ) showed relatively higher soil pH than the intercropped ( $T_1$ ,  $T_2$ ,  $T_3$ ,  $T_4$ ) and weedy plots ( $T_8$ ). Especially among  $T_5$ ,  $T_6$  and  $T_7$ , irrespective of the sampling date, the pH of the glyphosate treated plots ( $T_6$ ) was significantly higher than the intercropped ( $T_1$ ,  $T_2$ ,  $T_3$ ,  $T_4$ ) and weedy plots ( $T_8$ ).

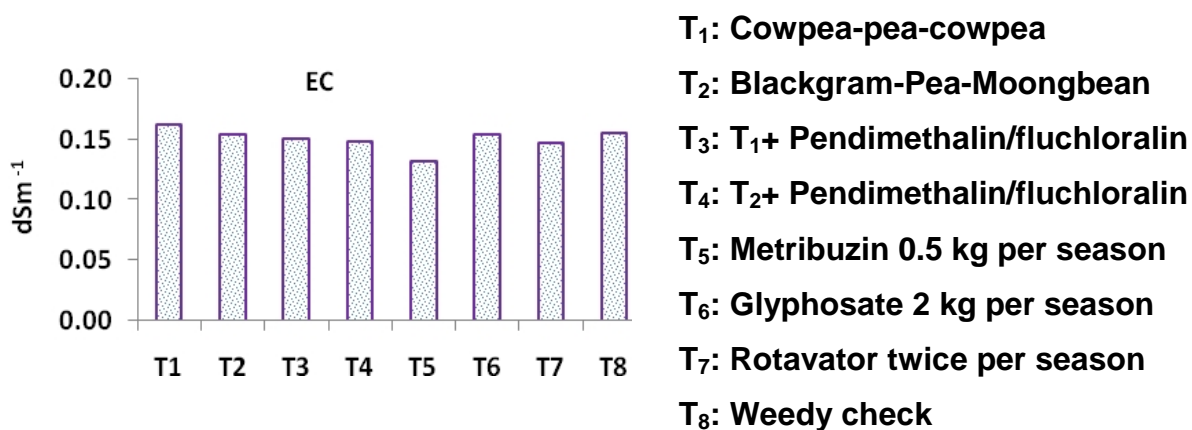


**Fig.4.3.** Impact of weed management practices on pH of the soil in mango orchard.

#### 4.2.2 Impact on Electrical conductivity

To study the impact of different weed management practices on soil Electrical conductivity, soil samples were taken at the beginning, mid and end of both the seasons under study and analysed using the standard procedures.

The pooled data over the sampling dates showed that the mean EC values of soil under different weed management practices varied within an insignificant range of 0.15-0.16  $\text{dSm}^{-1}$  (Fig.4.4).



**Fig.4.4. Impact of weed management practices on EC of soil in mango orchard.**

#### 4.2.3 Impact on organic carbon content

To study the impact of different weed management practices on organic carbon content, soil samples were taken and analysed using the standard procedures.

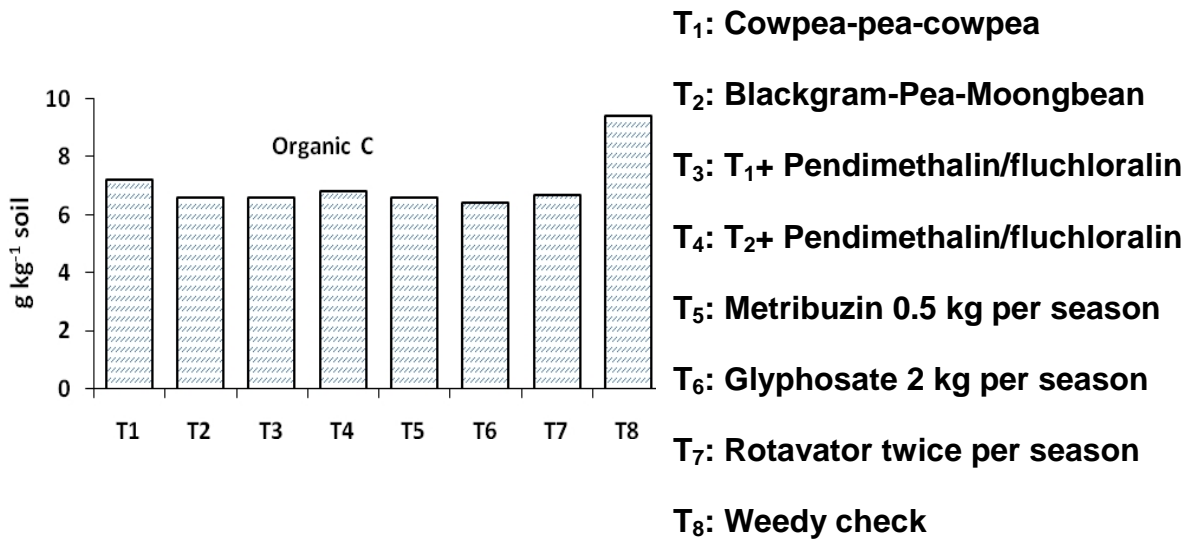
**Table 4.3: Impact of different weed management practices on soil organic carbon content (g/kg) of the soil in mango orchard**

Treatments	Cropping season					
	Kharif (2011)			Rabi (2011-12)		
	Date of soil sampling			Date of soil sampling		
	10 Jul	19 Aug	10 Oct	1 Dec	9Jan	6 Mar
T1: Cowpea-pea-cowpea	0.65	0.73	0.72	0.80	0.71	0.73
T2: Blackgram-Pea-Moongbean	0.59	0.52	0.69	0.83	0.64	0.67
T3:T1+ Pendimethalin/fluchloralin	0.62	0.62	0.66	0.76	0.64	0.69
T4: T2+ Pendimethalin/fluchloralin	0.57	0.72	0.63	0.81	0.67	0.67
T5: Metribuzin 0.5 kg in each season	0.71	0.58	0.73	0.70	0.53	0.72
T6: Glyphosate 2 kg in each season	0.75	0.56	0.64	0.75	0.56	0.56
T7: Mechanical (Rotavator) weeding	0.85	0.57	0.57	0.77	0.61	0.63
T8: Weedy check	1.01	1.00	0.92	0.83	0.88	0.99
<b>CD(0.05)</b>	<b>0.10</b>	<b>0.08</b>	<b>0.11</b>	<b>0.10</b>	<b>0.06</b>	<b>0.12</b>

The data presented in table 4.3 showed that, irrespective of sampling date, the permanent weedy plots (T<sub>8</sub>) showed significantly highest soil organic carbon content than the plots subjected to different weed control measures (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub>).

Compared to 1.01, 1.00, 0.92, 0.83, 0.88 and 0.99% in the weedy check, the organic carbon contents in the remaining treatments were within the ranges of 0.57-0.85, 0.52-0.73, 0.57-0.73, 0.77-0.83, 0.53-0.71 and 0.56-0.73%, respectively, on the corresponding dates of sampling.

The data pooled across the sampling dates showed that the mean organic carbon content of soil under different weed control measures varied within a very narrow range of 0.64-0.72%, which were significantly lower than the value of 0.94% as observed in the weedy plots (Fig.4.5). The data thus indicated that in general all the weed control measures had significant depressing effect on soil organic carbon content; however they did not vary greatly among them.



**Fig.4.5. Impact of different weed management practices on organic carbon content of soil in mango orchard.**

#### 4.2.4 Impact on available mineral nitrogen

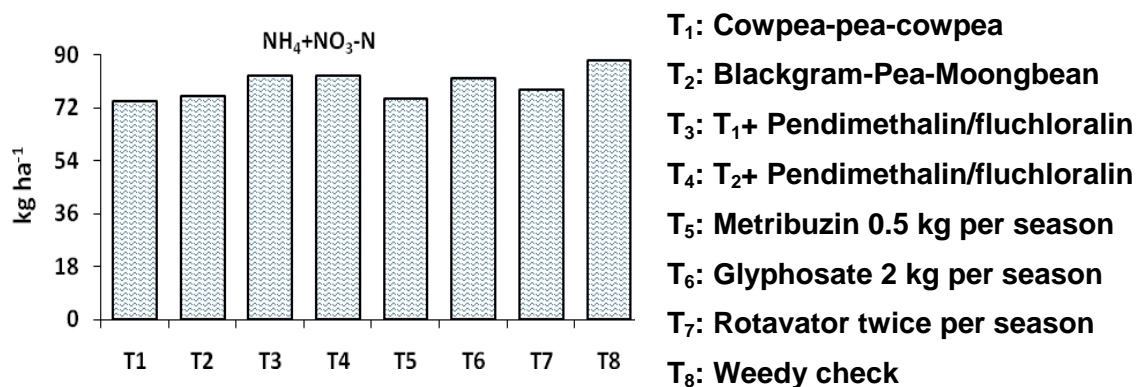
In order to assess the impact of different weed management practices on available mineral nitrogen content of the soil in mango orchard, soil samples were collected from (0-15 cm) depth on different dates in *kharif* and *rabi* seasons of 2011-12. The detailed results are presented in table 4.4.

The data showed that the weed control measures varied significantly among themselves in terms of ammonium+nitrate -nitrogen content of the soil during *kharif* season. However, no such differences among the treatments were noticed during *rabi* season. On the first date of sampling during *kharif* season, non-intercropping and weedy plots showed relatively higher available mineral nitrogen than intercropping plots. Weedy check (T<sub>8</sub>) and mechanically weeded plots (T<sub>7</sub>) showed significantly highest available mineral N content of 112 kg/ha, which was statistically similar to metribuzin (100 kg/ha) and glyphosate (104 kg/ha) treated plots, but significantly higher than that as recorded in intercropped plots (89, 96, 96 and 81 kg/ha in T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>, respectively). Similarly, significantly highest available mineral N content was observed in the weedy plots on subsequent sampling dates during *kharif* season. However, no such observation was recorded during *rabi* season. In *rabi* season, all the treatments were statistically similar to each other in terms of available mineral N content of soil.

**Table 4.4: Impact of different weed management practices on available mineral nitrogen content (kg/ha) of the soil in mango orchard**

Treatments	Cropping season					
	<i>Kharif (2011)</i>			<i>Rabi (2011-12)</i>		
	Date of soil sampling			Date of soil sampling		
	10 Jul	19 Aug	10 Oct	1 Dec	9Jan	6 Mar
T1: Cowpea-pea-cowpea	89	91	69	73	59	62
T2: Blackgram-Pea-Moongbean	96	89	91	66	59	60
T3:T1+ Pendimethalin/fluchloralin	96	103	72	71	62	62
T4: T2+ Pendimethalin/fluchloralin	81	103	88	68	60	65
T5: Metribuzin 0.5 kg in each season	100	99	75	60	62	60
T6: Glyphosate 2 kg in each season	104	101	79	65	62	58
T7: Mechanical (Rotavator) weeding	112	109	68	63	59	59
T8: Weedy check	112	126	103	62	60	62
<b>CD (0.05)</b>	<b>13</b>	<b>15</b>	<b>11</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>

The available mineral N content data was pooled across the sampling dates and represented graphically in fig.4.6. The mean values of different treatments showed that the available mineral N content was significantly highest in the weedy check treatment. There was, however, no significant variation among the remaining treatments.



**Fig.4.6. Impact of weed management practices on available mineral N content of soil in mango orchard.**

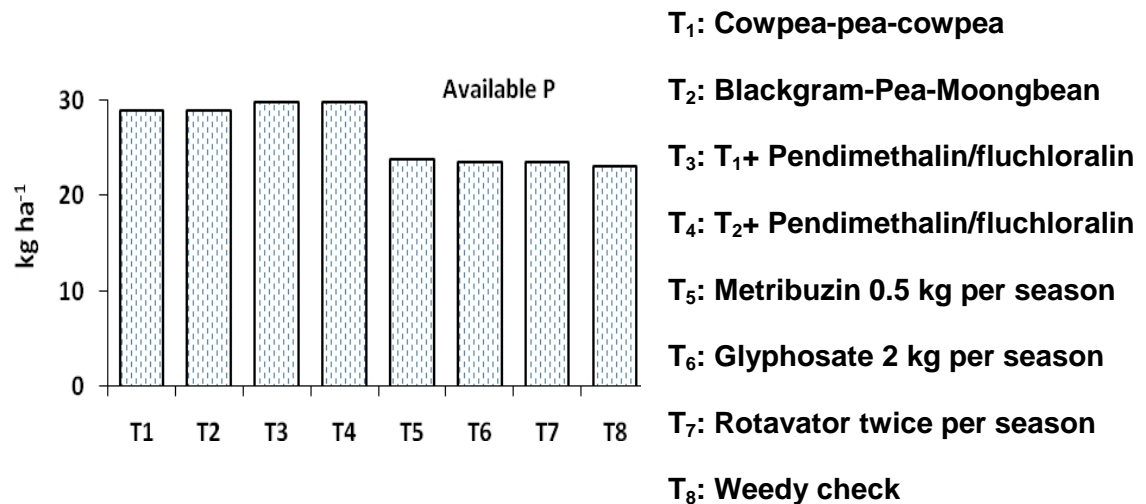
#### 4.2.5 Impact on available phosphorus content

In order to assess the impact of different weed management practices on available phosphorous content of the soil in mango orchard, soil samples were collected from (0-15 cm) depth on different dates during *kharif* and *rabi* seasons. The detailed results are presented in table 4.5.

**Table 4.5: Impact of different weed management practices on the available phosphorus content (kg/ha) of the soil in mango orchard.**

Treatments	Cropping season					
	<i>Kharif</i> (2011)			<i>Rabi</i> (2011-12)		
	Date of soil sampling			Date of soil sampling		
	10 July	19 Aug	10 Oct	1 Dec	9 Jan	6 Mar
T1: Cowpea-pea-cowpea	42.3	27.3	22.7	32.5	25.8	23.7
T2: Blackgram-Pea-Moongbean	43.7	27.7	21.8	30.5	26.0	24.6
T3: T <sub>1</sub> +Pendimethalin/fluchloralin	43.3	27.4	22.8	32.7	27.8	24.5
T4: T <sub>2</sub> + Pendimethalin/fluchloralin	41.4	29.1	23.6	34.5	27.3	22.9
T5: Metribuzin 0.5 kg in each season	34.4	20.7	22.7	24.5	19.8	20.8
T6: Glyphosate 2 kg in each season	34.8	21.9	21.0	20.4	21.4	21.5
T7: Mechanical (Rotavator) weeding	35.5	20.0	17.8	24.0	21.2	22.4
T8: Weedy check	32.8	20.1	20.8	23.1	21.2	20.6
<b>CD (0.05)</b>	<b>3.6</b>	<b>2.3</b>	<b>3.1</b>	<b>4.5</b>	<b>2.6</b>	<b>2.3</b>

The data in general showed that the available phosphorus content of the soil varied significantly under different weed management practices. On the first date of sampling under investigation, i.e. July 10, 2011, the range of available phosphorus content varied from 43.7-32.8 kg/ha in the different treatments. The highest available phosphorus content was recorded in T<sub>2</sub> which was statistically similar to T<sub>1</sub>, T<sub>3</sub> and T<sub>4</sub>. The lowest available phosphorus content was recorded in T<sub>8</sub> which was at par with T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub>. More or less similar trend was noticed during the study period. The data showed relatively higher available P content in all the treatments in the beginning of the *kharif* season, compared to the samples collected from the corresponding treatments at the later period of the season. Similar observation was recorded during *rabi* season also, but only in the intercropped plots (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>) that received fertilizer P as basal dose in each season. The available P content in the non-intercropping treatments (T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub> and T<sub>8</sub>), receiving no fertilizer P, was higher only at the beginning of the *kharif* season, which decreased substantially by the end of August and remained more or less stable during the subsequent period of study, i.e. till the end of *rabi* season.



**Fig.4.7. Impact of weed management practices on available P content of soil in mango orchard.**

The data pooled across the sampling dates (Fig.4.7), indicates that the available phosphorus content of the intercropped plots, i.e. T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>, did not differ among themselves and these plots showed significantly higher available phosphorus than the plots receiving sole chemical (T<sub>5</sub> and T<sub>6</sub>) and mechanical (T<sub>7</sub>) weed control measures or no weed control measure (T<sub>8</sub>).

#### 4.2.6 Impact on available potassium content

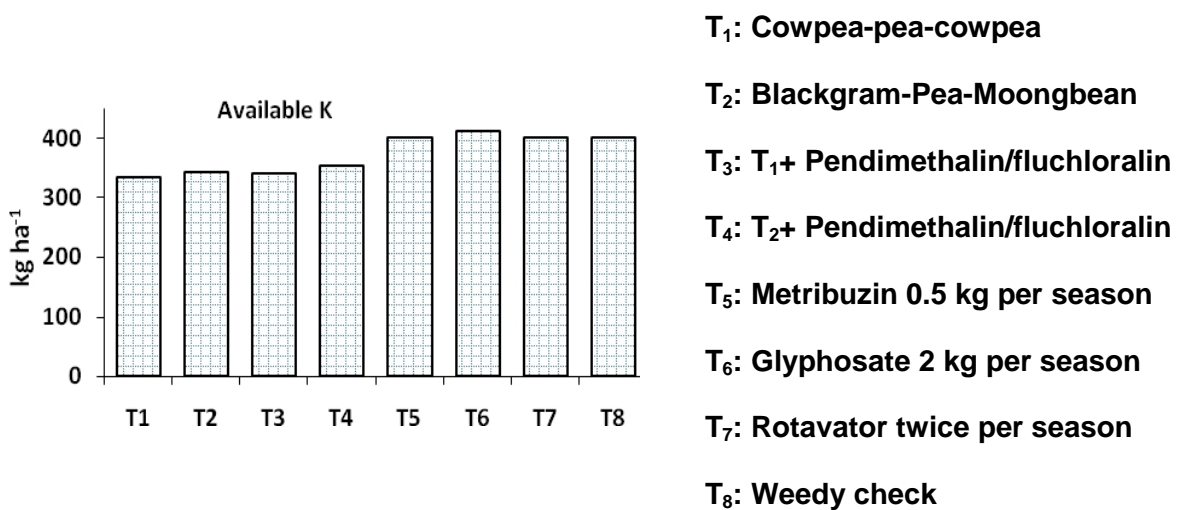
In order to assess the impact of different weed management practices on available potassium content of the soil in mango orchard, soil samples were collected from (0-15 cm) depth at different dates in *kharif* and *rabi* seasons. The detailed results are presented in table 4.6.

**Table 4.6: Impact of different weed management practices on available K content (kg/ha) of the soil in mango orchard.**

Treatments	Cropping season					
	<i>Kharif</i> (2011)			<i>Rabi</i> (2011-12)		
	Date of soil sampling			Date of soil sampling		
	10 Jul	19 Aug	10 Oct	1 Dec	9 Jan	6 Mar
T1: Cowpea-pea-cowpea	428	318	229	338	367	321
T2: Blackgram-Pea-Moongbean	437	299	300	304	376	342
T3:T1+ Pendimethalin/fluchloralin	460	302	256	343	360	322
T4: T2+ Pendimethalin/fluchloralin	426	310	336	349	379	324
T5: Metribuzin 0.5 kg in each season	448	365	404	392	423	382
T6: Glyphosate 2 kg in each season	459	392	433	355	417	411
T7: Mechanical (Rotavator) weeding	452	321	376	426	403	433
T8: Weedy check	437	366	408	429	362	411
<b>CD (0.05)</b>	<b>32</b>	<b>38</b>	<b>44</b>	<b>42</b>	<b>44</b>	<b>24</b>

The data in general showed that the available K content of the soil was slightly higher in the beginning of the *kharif* season in all the treatments, compared to the data as recorded during subsequent period of study.

The pooled data across the sampling dates (Fig.4.8) showed that available K content in the treatments under different intercropping, i.e. T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>, were relatively lower than that recorded in the remaining treatments, viz. T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub> and T<sub>8</sub>, where no intercrop was taken.



**Fig.4.8.** Impact of weed management practices on available K content of soil in mango orchard.

### 4.3 Impact of cultural chemical and mechanical weed management practices on soil Biological attributes in mango orchard

In order to evaluate the impact of cultural, chemical and mechanical weed management practices on soil biological attributes, viz. soil microbial biomass carbon, number of nodules/plant, oven dry weight of nodules and oven dry weight of plant biomass were determined at 45 days after sowing in *rabi* season. Results obtained are presented in following sub heads.

### 4.3.1 Impact on soil microbial biomass carbon

In order to assess the impact of different weed management practices on soil microbial biomass carbon content of the soil in mango orchard, soil samples were collected and analyzed using the standard procedure. The data are presented in table 4.7.

The data indicated that the highest microbial biomass carbon content was observed in mechanical weed plot i.e. 369 ( $\mu\text{g/g}$ ) in followed by Intercropped plot i.e. 358 ( $\mu\text{g/g}$ ) in  $T_1$ ,  $T_2$  and  $T_8$  receiving plots were observed almost at par i.e. 347 ( $\mu\text{g/g}$ ) and 348 ( $\mu\text{g/g}$ ) respectively herbicide receiving plots, viz.  $T_3$ ,  $T_4$ ,  $T_5$  and  $T_6$  showed comparatively lower soil microbial biomass carbon than non herbicide treated plots. Among herbicide treated plot the lowest soil microbial biomass carbon was noticed in glyphosate treated plot i.e. 139 ( $\mu\text{g/g}$ ).

**Table 4.7: Impact of different weed management practices on soil microbial biomass carbon content ( $\mu\text{g/g}$ ) of the soil at 45 days after sowing in mango orchard.**

Treatments	Soil microbial biomass carbon ( $\mu\text{g/g}$ )
$T_1$ : Cowpea-pea-cowpea	358
$T_2$ : Blackgram-Pea-Moongbean	347
$T_3$ : $T_1$ + Pendimethalin/fluchloralin	297
$T_4$ : $T_2$ + Pendimethalin/fluchloralin	241
$T_5$ : Metribuzin 0.5 kg in each season	230
$T_6$ : Glyphosate 2 kg in each season	139
$T_7$ : Mechanical (Rotavator) weeding	369
$T_8$ : Weedy check	348
<b>CD(0.05)</b>	38

### 4.3.2 Impact of chemical weed control measures on nodulation in pea grown as intercrop in mango orchard

In order to evaluate the impact of chemical weed control measures on nodulation, pea plants along with roots and nodules were collected from the intercropped plots at 45 days after sowing. The data on nodule count, and dry matters of nodule, shoot and root are presented in table 4.8.

**Table: 4.8. Impact of chemical weed control measure on nodule and plant parameters of field pea at 45 days after sowing in mango orchard**

Treatments	Nodule		Plant parameter		
	Count/ Plant	Dry matter (g/plant)	Root dry matter (g/plant)	Shoot dry matter (g/plant)	Root : Shoot ratio
T1: Cowpea-pea -cowpea intercrop	109	0.113	0.123	2.05	0.060
T2: Blackgram-Pea -Moongbean intercrop	97	0.130	0.136	2.09	0.066
T3: T1+ Pendimethalin /fluchloralin	82	0.080	0.119	2.07	0.057
T4: T2+ Pendimethalin /fluchloralin	64	0.053	0.128	2.18	0.059
T <sub>5</sub> : Metribuzin 0.5 kg in each season	-	-	-	-	-
T <sub>6</sub> : Glyphosate 2 kg in each season	-	-	-	-	-
T <sub>7</sub> : Mechanical (Rotavator) weeding	-	-	-	-	-
T <sub>8</sub> : Weedy check	-	-	-	-	-

The data indicated that the highest number of nodule was counted in T1, followed by T2, T3 and T4. Compared to T1, Nodule count in T3 was lower by roughly 25%. Similarly, about 34% lower nodule count was recorded in T4,

compared to T2. This indicated that application of pendimethalin adversely affected nodulation in pea in both cowpea-pea-cowpea and blackgram-pea-mungbean intercropping sequences. Similar to nodule count, 29-59% lower nodule dry biomass of pea was also recorded when pendimethalin was applied. The root- and shoot- dry biomass of pea in the given treatments varied within a marginal range of 0.119-0.136 and 2.05-2.18 g/plant, respectively. This indicated that the pendimethalin was harmful to nodulation but not to vegetative growth of pea.

## CHAPTER - V

### DISCUSSION

The present investigation was carried out on Directorate of Weed Science Research farm, Jabalpur for characterization of biological, physical and chemical properties of soil. The relevant result, which has been dealt elsewhere, has been discussed here.

#### 5.1 Discussion on physical attributes:

The basic infiltration rate as recorded in the permanently weedy plots (T<sub>8</sub>) was at par with intercropped plots T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, but it was significantly higher as compared to the treatments with sole chemical and mechanical measures (Table 4.1). More or less similar observation was recorded in case of cumulative infiltration vis-à-vis basic infiltration rate. The figure indicated that, during the time span of 305 minutes, the cumulative infiltration in the intercropped plots (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>) varied from 147-195 mm. Compared to this, much lower cumulative infiltration values ranging from 53 to 63 mm were recorded in the plots under sole chemical (T<sub>5</sub>, T<sub>6</sub>) and mechanical (T<sub>7</sub>) measures. The weedy plots (T<sub>8</sub>) showed the cumulative infiltration of 174 mm, which was well within the range as observed in case of intercropped plots. Overall, the data showed that the infiltration was better in the plots that remained under vegetative cover, i.e. in T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> and T<sub>8</sub>, compared to the plots that had relatively much lesser vegetative growth (T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub>) due to chemical/mechanical weed control measures.

The weedy check plots contained the significantly highest penetration resistance for 0-5 cm depth. It may be noted that the plots under weedy check treatment (T<sub>8</sub>) had thick growth of perennial weeds, especially *Cyanodon dactylon*. Thus the observation of significantly highest penetration force in this treatment could be attributed to the root system of *Cyanodon dactylon* which was very dense at the soil surface of this treatment. High penetration resistance of the weedy plots however had no restricting effects on infiltration. Weedy plots (T<sub>8</sub>), similar to intercropped plots (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>), maintained a reasonably high

infiltration compared to the virtually clean bare plots (T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub>). This coincided with results previously found by Theirfelder *et al.* (2005) who attributed this to either good aggregation along with good biological fixation of grass roots (as in T<sub>8</sub>) or a good water transportation system from the root of legumes grown as intercrops (as in T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>) and soil cover. This hindered the soil from drying out during the dry season, thus preventing the development of soil crusts and seals. The weedy and intercropped plots basically maintained its soil functions and did not develop soil crusts as a consequence of high biological activity, plant roots, superficial soil protection and biological stabilization (Gasser 1990, Steiner 1996).

## **5.2 Discussion on Chemical attributes:**

The results presented in the previous chapter shows that there were significant variation in the available N, P and K content in the soil samples collected at different times of the study period (Tables 4.4, 4.5 and 4.6). In general the values were relatively higher during the *kharif* than the *rabi* season. The data recorded in the present investigation in respect to the seasonal variation in NH<sub>4</sub>+NO<sub>3</sub> - N is similar to the report of Patra *et al.* (2001), who observed that, compared to February-March, there were relatively higher NH<sub>4</sub> and NO<sub>3</sub> nitrogen content in soil under legume based forage production system in the month of July. The mineralization and immobilization phenomena of soil N is expected to be more pronounced during *kharif* than during *rabi*. This could be the probable reason why the effect of the floor management treatments on available nutrient contents was relatively prominent during *kharif* than the *rabi* season. Seasonal changes in the mineral N and P content in the forest soil was reported earlier by Czepinska-Kaminska *et al.* (1999). Variation in the mineral N content of an apple orchard soil at different sampling dates was also reported by Wrona and Sadowski (2004). Parzych *et al.* (2011) concluded that the distribution and accumulation of mineral forms of N and P are considerably affected by atmospheric conditions such as temperature, humidity and precipitation.

Substantially higher loss of N due to leaching of nitrate-N from the glyphosate treated plots than from the grass plots, as a groundcover management system in apple orchard, was reported by Merwin (2004). Thus the significantly higher available mineral-N content in the samples collected from weedy plots in the months of August and September 2011, relative to the metribuzin, glyphosate and rotavator treatments, as was observed in the present investigation, could be attributed to relatively lesser loss of N from the weedy plots than from the later plots during rainy season.

The results showed that there were significant variation in the organic carbon (Fig.4.5), and available mineral N (Fig.4.6), P (Fig.4.7) and K (Fig.4.8) contents among the treatments. The effect of different floor management treatments on the nutrient availability have earlier been reported by various workers (Bhat and Khokhar 2009, Kumar and Chauhan 2003). All the weed control measures showed significantly lower organic carbon content than the weedy plots (Fig.4.5). It may be noted that except weedy check, all the remaining treatments received a rotavator operation in the beginning of each cropping season, since *kharif* 2008, which could have accelerated organic matter loss in the later treatments compared to the weedy check (Cambardella and Elliott 1993). A significant increase in organic matter content in grass lane over the pre- and post-emergent herbicide treatments in an apple orchard floor was reported by Laurent *et al.* (2008). Similar observation was also recorded in this investigation, showing significantly lower soil organic matter content in the metribuzin (T<sub>5</sub>) and glyphosate (T<sub>6</sub>) treatments than the weedy plots (T<sub>8</sub>).

Significantly higher mineral N content in the weedy plots (Fig.4.6), as observed in the study, could be attributed to the significantly higher organic carbon content in these plots over the remaining treatments.

There was no significant variation in the available P (Fig.4.7) content among the metribuzin, glyphosate, mechanical weeding and weedy check treatments. Similar observation vis-à-vis glyphosate, Mowed sod grass and grass lane treatments in an apple orchard was recorded by Laurent *et al.* (2008).

Available P contents in the intercropping treatments (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>) were significantly higher over the remaining treatments (Fig.4.7). The probable reasons for the given observation could be due the fact that the intercropped plots received the application of P @ 46 kg P<sub>2</sub>O<sub>5</sub>/ha and 18 kg N/ha through DAP in the beginning of each cropping seasons, i.e. *kharif*, *rabi* and summer, since *kharif* 2008. Whereas, no fertilizer was applied to the remaining treatments (T<sub>5</sub>, T<sub>6</sub>, T<sub>7</sub> and T<sub>8</sub>). The observation under the long term fertilizer trials also indicated that the continuous application of P at the recommended levels favours build up of available P in soil ([www.iiss.nic.in/IISS%20Web%20LTFE%20July2009.pdf](http://www.iiss.nic.in/IISS%20Web%20LTFE%20July2009.pdf)).

Contrary to available P, available K contents in the soil under intercropping treatments were significantly lower than the remaining treatments (Fig.4.8). Intensive intercropping in the treatments T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> without any application of fertilizer K could have caused the depletion in available soil K in these treatments. Depletion in K content of the soil was also noted in other orchards with different intercrops (Gonge *et al.* 1997, Ghosh and Pal 2010).

Although, the weed management treatments have not shown any significant effect on soil EC; soil pH was significantly higher under glyphosate treatment, compared to other treatments (Fig.4.3). Compared to a pH value of 6.4 under grass lane, a relatively higher pH value of 7.0 under the ground management system with post-emergence application of glyphosate for 14 years in an apple orchard was earlier noticed by Laurent *et al.* (2008). Similarly, effect of herbicide application on soil pH had earlier been reported by various other workers (Ayansina and Oso 2006).

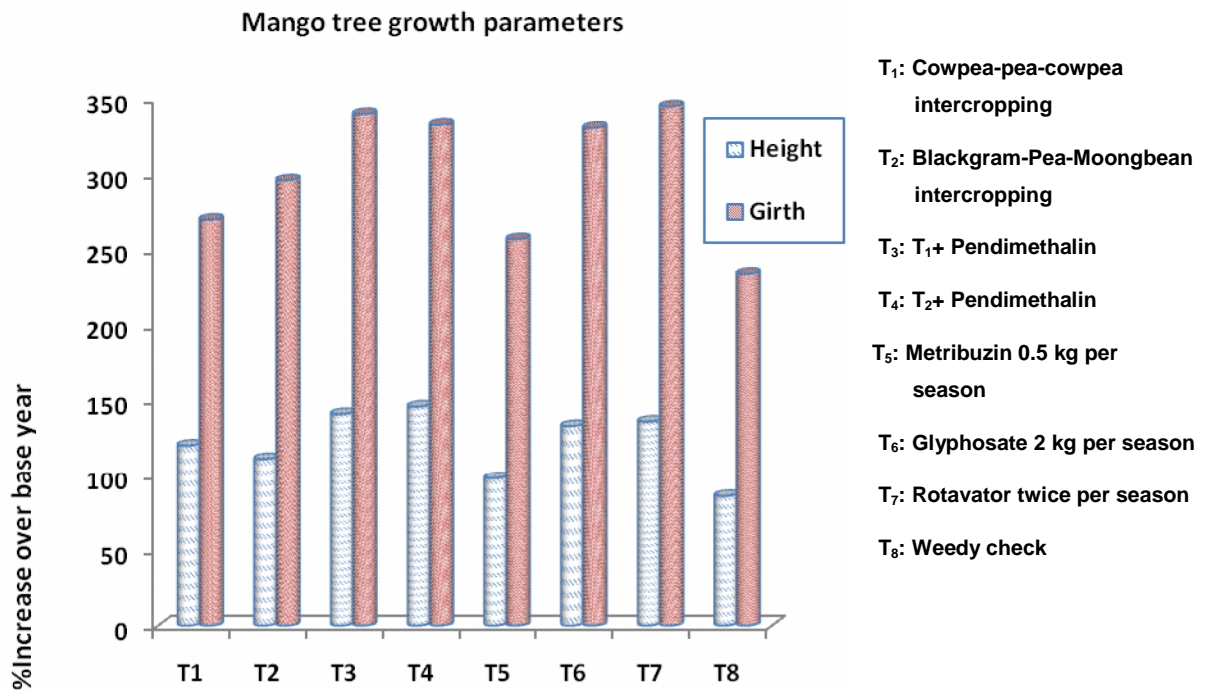
### **5.3 Discussion on biological attributes:**

In the given investigation, soil microbial biomass carbon was significantly lower in the plots receiving herbicides (T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, T<sub>6</sub>), compared to other treatments (Table 4.8). It is possible that there was some direct chemical influence of the herbicides that has altered the microbial communities in these treatments ( Laurent *et al.* 2008). Metribuzin was applied as a pre-emergence herbicide immediately after initial rotavator operation in the beginning

of each season, and a profuse growth of weeds was observed in this treatment at later part of the season. Glyphosate treatment, however, was given after one month of initial rotavator operation, and this treatment gave the season long virtually weed free environment in the plots. As a result, dry biomass of weeds in the metribuzin treated plots was higher than that observed in glyphosate treated plots during a given season (DWSR 2011). Consequently, when the plots were subjected to rotavator operation in the beginning of the subsequent season, there was relatively greater recycling of weed biomass in the metribuzin treatment than the other one. This condition providing more organic inputs to soil during all the three seasons, beginning with *kharif* 2008, may explain the significant difference in soil microbial biomass carbon between these two herbicide treatments (T<sub>5</sub>, T<sub>6</sub>), as observed in the given study. Similarly, organic inputs from leaf droppings and from the below-ground biomass of the intercrops in the pendimethalin treated plots (T<sub>3</sub>, T<sub>4</sub>) could be responsible for significantly higher soil microbial biomass carbon observed in the study, relative to glyphosate treatment.

Although there was no effect on vegetative growth of pea; both the count and dry biomass of nodule in the pea were lower when combined with pendimethalin, than when grown alone as an intercrop in the mango orchard floor (Table 4.8). This could be due to the direct effect of the herbicide on pea-*Rhizobium* interaction. The adverse impacts of herbicides on nodulation in legume crops have earlier been reported by various workers (Singh and Wright 2006, Bollich *et al.* 1988).

The weedy plots in the given experiment was densely infested by *Cyanodon dactylon* which have acted as a living mulch, and thereby maintained relatively better soil health as reported and discussed above. However, tree growth in this treatment was inferior to all other treatments; the relatively better growth was recorded in the glyphosate (T<sub>6</sub>), sole mechanical cultivation (T<sub>7</sub>) and intercropping combined with pendimethalin treatments (T<sub>3</sub>, T<sub>4</sub>) (Fig.5.1).



**Fig.5.1. Effect of weed management treatments in orchard on mango tree growth.**

Similar observation was reported by Hoagland *et al.* (2008), who attributed it to the competition for soil moisture, root spatial competition or soil borne pathogens and parasites that are effectively controlled with cultivation. Yao *et al.* (2005) also reported that the trunk cross sectional area of the apple tree was greater under the floor management with glyphosate treatment than under grass. This could also be the probable reason for relatively better growth of mango plants in the intercropping treatments combined with pendimethalin, than the sole intercroppings that showed relatively higher growth of grasses; although all the intercropping treatments were similar in terms of soil quality parameters except soil microbial biomass carbon. Better growth, especially height, of *Mosambi* plants was also observed by Ghosh and Pal (2010) where cowpea, groundnut and cluster beans were grown as intercrops.

## CHAPTER – VI

### SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

#### Summary

The present investigation were undertaken to know the impact of weed management practices on soil health indicators in a mango orchard with and without intercropping. The prime objectives are as under:

- i. To study the impact of cultural, chemical and mechanical weed management practices in a mango orchard on different soil health indicators i.e. physical, chemical and biological.
- ii. To study the impact of herbicides on nodulation in pea grown as intercrop in a mango orchard

During the present investigation soil samples were taken from the 32 plots (having an area of about 0.44 ha) of a mango orchard established recently in the Directorate of Weed Science Research farm, Jabalpur. These samples were analyzed for their various physico-chemical and biological properties. The physical properties such as bulk density, porosity, infiltration and penetration force were determined by standard procedure as described by Saha (2004). The chemical characteristics viz. soil pH, electrical conductivity, soil organic carbon, available soil mineral nitrogen, available phosphorus, available potassium have been determined by following standard procedures (Black, 1965). The soil microbial biomass carbon, taken as an indicator of soil biological properties, was determined by following chloroform fumigation extraction method (Brookes *et al.*, 1985); observation on nodulation in pea, grown as intercrop in mango orchard, was recorded by physically collecting, counting and weighing the nodules.

## Conclusion

Cultural, mechanical and chemical control measures were evaluated to manage the weeds in a newly planted mango orchard at the Directorate of Weed Science Research, Jabalpur. The mango orchard was planted in the square grids of 9 m length. The experiment was initiated during *kharif* 2008 with 8 floor management treatments consisting of two cultural practices viz. growing intercrops during *kharif*, *rabi* and summer seasons by following cowpea-pea-cowpea and black gram-pea-green gram sequences, two integrated weed management practices viz. growing the abovementioned intercrops in combination with the application of fluchloralin (1.0 kg/ha PPI) /pendimethalin (1.0 kg/ha PE) in each season, two chemical weed control measures viz. application of metribuzin (0.5 kg/ha PE) and glyphosate (2 kg/ha Post) in each season, operating tractor drawn rotavator twice in each season as a mechanical weed control measure, and a weedy check as control. The experiment was laid out in the orchard floor by following randomized block design with 4 replications of each treatment. There were two mango plants at an interval of 9 m distance along the axis of each experimental plot of 8 m x 17 m dimension in such a way that each mango plant was at a distance of 4.5 m from the centre and 4.0 m from the adjoining borders of the plot. Each mango plant received the application of 5 kg FYM on dry weight basis and 100 g DAP in its basin of 1 m diameter in the beginning of *kharif* season of each year. The each intercrop received the basal application of 18 kg N/ha and 46 kg P<sub>2</sub>O<sub>5</sub>/ha through DAP. No fertilizer was applied to the non-intercropped plots. Irrigation was given by using sprinkler system as and when needed.

Observations were recorded during *kharif* 2011 and *rabi* 2011-12 on soil chemical parameters, viz. pH, EC, organic carbon available mineral nitrogen available phosphorus and available potassium; soil physical parameters, viz. bulk density, porosity, in situ infiltration and penetration force; and soil biological parameters, viz. soil microbial biomass carbon, and also on nodulation parameters of pea grown as intercrop.

On the basis of the results obtained, it may be concluded that:

1. Managing weeds in the newly established mango orchard by using cultural, chemical and mechanical means favoured the trees to achieve better growth.

2. The practice of no weed management, and consequent growth of grasses, increased the penetration resistance of the surface soil.
3. The mechanical (repeated rotavator operation) and sole chemical measures (application of metribuzin and glyphosate) hampered the development of soil physical quality in terms of infiltration rate. Besides that the chemical treatments also hampered the development of soil biological health in terms of soil microbial biomass carbon.
4. Growing legumes, with recommended doses of N and P, as intercrops in the orchard improved soil physical health in terms of infiltration rate and penetration resistance. These treatments also maintained good soil biological health in terms of soil microbial biomass carbon, and improved soil available P status.
5. Application of pendimethalin to pea adversely affected the nodulation parameters and soil microbial biomass carbon.

Thus keeping in view all the soil parameters studied in this investigation, it is concluded that the intercropping treatments were better than the sole mechanical and chemical treatments in terms of overall soil health.

### **Suggestion for the further work**

- Growing leguminous intercrops with recommended N and P was relatively better than other treatments in terms of soil health, but showed a slight decline in available K. Hence, it is suggested to include fertilizer K in these treatments for making them much better option of managing weeds in the orchard in view of the soil health.
- Growing leguminous intercrops in combination with pendimethalin, to some extent, harmed soil biological health, but performed better in terms of tree growth. Hence, in future course of research, attempt may be taken to find an alternative herbicide for legumes; which should have less toxic effect on nodulation and soil microbial biomass than pendimethalin.

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