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Influence of Integrated Nutrient Management on Red Leaf Index of Cotton and Incidence of Insect Pest and Disease in Cotton and Soybean Intercropping System

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMP designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors VVA and SJ managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at All India Coordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India to study the integrated nutrient management practices on red leaf index, insect pests and diseases in

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cotton and soybean intercropping system in 1:2 row proportion during *kharif* 2015. The study was undertaken to evaluate the sources of nutrients to red leaf index and incidence of insect pests and diseases. The field experiment was laid out in a randomised complete block design with three replications and twenty treatments. Treatment comprised of organic and inorganic sources of nutrients used in different combinations. Soybean introduced as intercrop in cotton with 40 x 10 cm spacing for soybean and 120 x 60 cm for cotton. There were no visual symptoms of leaf reddening at October 1st, and lowest red leaf index was observed in treatment receiving 100% RDF (recommended dose of fertiliser) for cotton and soybean + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}. At 40 DAS, lower incidence of *Spodoptera* larvae was observed in treatment receiving 100% RDF for cotton and soybean + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}, 100% RDF for cotton and soybean + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1} and 100% RDF for cotton and soybean + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}. At 85 DAS, lowest pod borer incidence was observed in treatment receiving 100% RDF for cotton and soybean + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1} compared to other treatments. Lower percent disease incidence of angular leaf spot of cotton was observed in 100% RDF for cotton and soybean + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1} than other treatments. At 65 DAS lower percent disease incidence of *Alternaria* leaf blight of cotton was observed in treatment receiving 100% RDF for cotton and soybean + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}, 100% RDF for cotton and soybean + vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1} and 100% RDF for cotton and soybean + vermicompost 1.25 t h^{-1} + Pongamia 2.5 t ha^{-1} compared to other treatments. It could be concluded that application of 100% RDF for cotton and soybean + Gliricidia 2.5 t ha^{-1} + Pongamia t ha^{-1} in cotton and soybean intercropping systems reduced the red leaf index and provide resistance to crop against insect pests and disease.

Keywords: Cotton; soybean; integrated nutrient management; intercropping; red leaf index; insect pests.

1. INTRODUCTION

Cotton is the most important vital crop of commerce to many countries. The introduction of Bt cotton which is known for its resistance against bollworms has brought a significant change in the cotton cultivation scenario of India during last decade. India stands first among all the cotton growing countries of the world with an area of 13 million hectare, which accounts to one fourth of the world cotton area and production of 5.95 million tonnes of seed cotton. In India, the productivity of cotton is 461 kg per hectare as compared to Australia, Turkey and Brazil with 2,151, 1,484 and 1,465 kg per hectare, respectively [1]. Area under Bt cotton has increased from 2014 to 2016, however, the yield levels are reducing. There are many reasons for the reduction in cotton productivity. The primary cause being area under rainfed conditions which predominate over an irrigated area in the state and the country. More than 50 percent of rainfed cotton is grown under erratic and low rainfall, without proper fertilisation and plant protection measures. Thus, low yield levels prevailing in the country could be attributed to the genetic, physiological and agronomic factors. The main agronomic factors are improper tillage, non-incorporation of residue, decline in soil fertility and nutrient imbalance in the soil. Among the physiological factors, leaf reddening, bad boll opening and boll shedding and drying of squares are the main causes for low yield [2]. Leaf reddening symptom in cotton is not a new problem and it was reported long back [3]. Leaf reddening malady in cotton is called in different names across the world as red-leaf-disease, bronze wilt, copper top, early foliar decline, sudden wilt, phloem wilt, red leaf, red wilt and anthocyanosis [4]. The red leaf syndrome in cotton was reported in various parts of the world like America [5]; New guinea [6]; Nigeria [7] Netherland, Uganda, South Africa [8] and India [9]. [10] considered leaf reddening to be a physiological disorder and [8] also opined the same reason for premature leaf reddening in American Cotton. According to survey report of Hosmath (2011), 93 per cent farmers had faced this problem and the seed cotton yield loss was upto 60 percent [11] (Bhatt and Patil, 1976). However, [5] opined that it is due to an attack of aphids. [10] considered that the jassids might be carrying the disease. [12] opined that red leaf disease is transmitted by aphids from diseased to healthy plants. Both reduced and excessive supply of many plant nutrients could possibly aggravate susceptibility to pests and diseases. Integrated nutrient management ensures optimal crop growth, development and resists against pests and diseases. Suitable management practices like intercropping and judicious combination of organic and inorganic manures are considered as yield improvement technologies and can avoid environmental pollution. However, which intercrop is suitable for the study area and what combination of nutrients will perform better needs to be known [13]. This study was undertaken to evaluate the various sources of nutrients to sustain the productivity and pest and disease incidence of Bt cotton and soybean intercropping.

2. MATERIALS AND METHODS

A field experiment was conducted to study the integrated nutrient management (INM) on red leaf index on cotton and incidence of insect pest and diseases in cotton and soybean intercropping system in 1:2 row proportion during *kharif* (July month) 2015 at plot 101 'D' block, University of Agricultural Sciences, Dharwad, Karnataka (India). Soil of the experimental site was *vertisol,* having 0.51% organic carbon, 281 kg ha^{-1} available N, 34 kg ha^{-1} available P_2O_5 and 312 kg ha^{-1} available K_2O, 7.3 pH and 0.35 EC. The field experiment was laid out in randomised complete block design with three replications and twenty treatments as furnished in the tables. Sowing was done by adopting 120 cm x 60 cm row spacing for cotton and 40 cm x 10 cm for soybean in intercropping system (1:2) during *kharif* season on 9.7.2015. As per the treatments the organic manure (FYM) and green leaf manures (gliricidia and pongamia) were applied 15 days before sowing of the crop. Vermicompost was spot applied to soil before dibbling of seeds. RDF was applied to both crops in intercropping system according to population (100:50:50 and 40:80:25 kg N, P_2O_5 and K_2O ha^{-1} for Cotton and Soybean, respectively) [14].

2.1 Red Leaf Index Estimation

For quantitative estimation of degree of leaf reddening in cotton, observations were recorded at October 1st (84 days after sowing), October 15th (97 days after sowing), October 30th (112 days after sowing) and November 15th (128 days after sowing) during 2015 as outlined by [15]. The number of leaves showing signs of reddening, partly or wholly were divided into five categories on the visual observations.

Grade '0' – When all the leaves were green or less than three leaves showed signs of reddening.
Grade '1' – When three leaves showed reddening.
Grade '2' – When more than three leaves were showing signs of reddening but young leaves were green.
Grade '3' – When all the leaves were showing reddening in patches.
Grade '4' – When the whole plant turned red.

2.2 Observation on Incidence of Insect Pests in Soybean

2.2.1 *Spodoptera* larvae per meter row length in soybean (mrl)

Observations were made at three places in each plot and mean was reported in number per meter row length (mrl) in soybean.

2.2.2 Pod borer incidence (*Cydia ptychora*) in soybean

Before harvesting, incidence of pod borer was recorded by uprooting five randomly selected plants in soybean leaving border rows. Total number of pods per plant and larvae per pod was recorded [16].

2.3 Observation on Diseases in Cotton

2.3.1 Disease score

Disease scores were made for Angular leaf spot and *Alternaria* leaf blight in cotton using disease rating scale (0-9) developed by [17].

Rating	Description
0 -	No infection
1 -	1-10 per cent of infection
3 -	10 – 25 per cent of infection
5 -	25-50 per cent of infection
7 -	50 – 75 per cent of infection
9 -	> 75 per cent of infection

Per cent disease index (PDI) = {(Sum of numerical ratings × 100) / (Number of leaves observed × Maximum disease rating)}

2.4 Statistical Analysis and Interpretation of Data

Statistical analysis was carried out based on mean values obtained. The level of significance used in 'F' and 'T' test was P = .05. The design of the experiment was randomised complete block design. The treatment means were compared by Duncan's Multiple Range Test (DMRT) at .05 level of probability [18].

3. RESULTS AND DISCUSSION

3.1 Red Leaf Index in Cotton

Leaf reddening is more of physiological disorder than a disease of cotton. In India its symptoms differ from region to region. In the present investigation, red leaf index differed significantly due to INM treatments. At October 15th (97 days after sowing), 30th (112 days after sowing) and November 15th (128 days after sowing), the highest red leaf index was observed in cotton sole crop and it was on par with T_1 (100 % RDF for cotton and soybean), except at October 15th (97 days after sowing). Lowest red leaf index was observed in T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}). It was due to the very nature of vermicompost, which supplies sufficient micronutrients in form to available plants readily, which react with native soil nutrients in a way that enhances their availability to crops thus resulting in improved physiological function of plants against red leaf index in low temperature conditions. Similar results were observed by [19], who reported that the red leaf was caused by the deficiency of nitrogen and micronutrients in leaves grown on light textured soil. However at October 1st (84 days after sowing), where there was no red leaf index reported.

3.2 Incidence of *Spodoptera litura* in Soybean

Incidence of *Spodoptera litura* (mrl^{-1}) in soybean differed significantly due to INM treatments (Table 2). Among the different treatments, lower incidence of *Spodoptera* larvae was observed in T_{16} (T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}), T_{17} (T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}) and T_{18} (T1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}). Vermicompost is the organic manure obtained by earthworm and microbes induced biodegradation of organic wastes, contains major and minor nutrients, secondary elements, plant growth regulators and antibiotics and vast populaton of fungi, bacteria, actinomycetes and protozoa [20]. Sole soybean crop recorded significantly higher incidence of *Spodoptera litura* (1.84 larvae mrl^{-1}) and it was on par with T_3 (150 % RDF for cotton and soybean) (1.78 larvae mrl^{-1}) compared to rest of the intercropping systems. Higher dose of nutrients beyond the optimum showed more succulence and susceptible to insect pests.

3.3 Pod Borer Incidence in Soybean

Incidence of pod borer in soybean differed significantly due to INM treatments (Table 2). Among the different treatments, lower pod borer incidence in soybean observed in T_{18} (T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha). However, T_3 (150 % RDF for cotton and soybean) recorded higher pod borer incidence (1.56 larvae pod^{-1}) in soybean and it was on par with sole soybean (1.60 larvae pod^{-1}). The decrease in pod borer incidence was to the tune of 90 per cent over T_3 (150 % RDF for cotton and soybean). Similar results were observed by [21], who reported that lower aphid infestation on bhendi and leaf hoppers in brinjal was observed with application of vermicompost.

3.4 Incidence of Angular Leaf Spot in Cotton

Incidence of angular leaf spot in cotton differed significantly due to INM treatments (Table 2). Among the different treatments, T_{16}, T_{17} and T_{18} recorded lower incidence of angular leaf spot in cotton. Green manure and vermicompost treatments showed lower incidence of angular leaf spot disease. Vermicompost undergoes decomposition to produce organic acids and releases the macro and micro nutrients in soil. They are involved in shikimate pathway, responsible for biosynthesis of phenolics, lignins and phytoalexins, which provide resistance to plants. However, T_3, T_2 (150 and 125% RDF for cotton and soybean, respectively) and cotton sole crop (12.1 PDI) recorded the highest incidence of angular leaf spot in cotton.

3.5 Incidence of *Alternaria* leaf Blight Disease in Cotton

Incidence of *Alternaria* leaf blight disease in cotton differed significantly due to INM treatments (Table 2). Among the different treatments, lower per cent disease incidence of *Alternaria* leaf blight of cotton was observed in T_{16}, T_{17} and T_{18}. Similarly, green manures like gliricida and pongamia after decomposition produce organic acids, which accelerates synthesis of pathogenesis related proteins [22]. However, the highest incidence of *Alternaria* leaf blight disease (14.1 PDI) in cotton was observed in T_3 (150 % RDF for cotton and soybean). Higher the applied chemical fertilizers than optimum more is succulence and susceptible to disease.

Table 1. Red leaf index in cotton as influenced by INM in cotton and soybean intercropping system during 2015-16

Treatments	**Red leaf index**			
	October 1st (84 DAS)	**October 15th (97 DAS)**	**October 30th (112 DAS)**	**November 15th (128 DAS)**
T_1: 100 % RDF for cotton and soybean	0.70 (0)	1.08a (0.67)	1.30ab (1.20)	1.25a (1.07)
T_2: 125 % RDF for cotton and soybean	0.70 (0)	0.84a (0.20)	1.05d-f (0.6)	1.10a-c (0.73)
T_3: 150 % RDF for cotton and soybean	0.70 (0)	0.84a (0.20)	1.11b-f (0.7)	0.98bc (0.47)
T_4: 100 % FYM and RDF for cotton and soybean (RC)	0.70 (0)	1.02a (0.53)	1.24a-d (1.1)	1.14ab (0.8)
T_5: T_1 + FYM 2.5 t ha^{-1}	0.70 (0)	0.94a (0.40)	1.19a-d (0.9)	1.10a-c (0.73)
T_6: T_1 + FYM 5 t ha^{-1}	0.70 (0)	0.94a (0.40)	1.30ab (1.2)	1.10a-c (0.73)
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	0.70 (0)	0.95a (0.40)	1.19a-d (0.9)	1.16ab (0.87)
T_8: T_1 + Gliricidia 5 t ha^{-1}	0.70 (0)	0.95a (0.40)	1.25a-c (1.1)	1.17ab (0.87)
T_9: T_1 + Pongamia 2.5 t ha^{-1}	0.70 (0)	0.94a (0.40)	1.16a-e (0.9)	1.20a (0.93)
T_{10}: T_1 + Pongamia 5 t ha^{-1}	0.70 (0)	0.87a (0.27)	1.30ab (1.2)	1.25a (1.07)
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	0.70 (0)	0.94a (0.40)	1.10c-f (0.7)	1.10a-c (0.73)
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	0.70 (0)	0.95a (0.40)	1.16a-e (0.9)	1.25a (1.07)
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	0.70 (0)	0.91a (0.33)	1.11b-f (0.7)	0.98bc (0.47)
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	0.70 (0)	0.91a (0.33)	1.10c-f (0.7)	0.98bc (0.47)
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	0.70 (0)	0.91a (0.33)	1.13b-f (0.8)	1.11a-c (0.73)
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	0.70 (0)	0.84a (0.20)	0.98ef (0.5)	0.98bc (0.47)
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	0.70 (0)	0.79a (0.13)	0.95f (0.4)	0.91c (0.33)
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	0.70 (0)	0.84a (0.20)	1.05d-f (0.6)	0.98bc (0.47)
T_{19}: Cotton sole crop (100 % RDF and FYM)	0.70 (0)	1.11a (0.73)	1.33a (1.3)	1.28a (1.13)
T_{20}: Soybean sole crop (100 % RDF and FYM)	-	-	-	-
Mean	**-**	**0.93**	**1.16**	**1.11**
S.E.M	**-**	**0.03**	**0.05**	**0.06**
C.V. (%)	**-**	**6.02**	**13.1**	**13.2**

Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check; Figures in the parenthesis are original values and analyzed data are subjected to square root transformations; DAS – Days after sowing

Table 2. Incidence of *Spodoptera litura* in soybean at 40 DAS and pod borer incidence in soybean at 85 DAS as influenced by INM in cotton and soybean intercropping system during 2015-16

Treatments	*Spodoptera* larvae at 40 DAS (per mrl)	Pod borer incidence at 85 DAS (number of larvae per pod)	Angular leaf spot disease	*Alternaria* leaf blight disease
T_1: 100 % RDF for cotton and soybean	1.30 (1.22) de	1.41 (1.48) a-c	10.1 (1.67) ab	8.13 (1.00) b
T_2: 125 % RDF for cotton and soybean	1.61 (2.11) bc	1.47 (1.67) a-c	12.1 (2.33) a	10.1 (1.67) ab
T_3: 150 % RDF for cotton and soybean	1.78 (2.67) ab	1.56 (1.93) a	12.1 (2.33) a	14.1 (3.00) a
T_4: 100 % FYM and RDF for cotton and soybean (RC)	1.43 (1.56) cd	1.43 (1.56) a-c	10.1 (1.67) ab	8.13 (1.00) b
T_5: T_1 + FYM 2.5 t ha^{-1}	1.58 (2.00) c	1.53 (1.85) ab	10.1 (1.67) ab	10.1 (1.67) ab
T_6: T_1 + FYM 5 t ha^{-1}	1.54 (1.89) c	1.53 (1.89) ab	10.1 (1.67) ab	8.13 (1.00) b
T_7: T_1 + Gliricidia 2.5 t ha^{-1}	1.43 (1.56) cd	1.54 (1.89) ab	5.42 (0.67) b	10.1 (1.67) ab
T_8: T_1 + Gliricidia 5 t ha^{-1}	1.43 (1.56) cd	1.02 (0.56) ef	8.13 (1.00) ab	10.1 (1.67) ab
T_9: T_1 + Pongamia 2.5 t ha^{-1}	1.58 (2.00) c	1.58 (2.00) a	8.13 (1.00) ab	8.13 (1.00) b
T_{10}: T_1 + Pongamia 5 t ha^{-1}	1.43 (1.56) cd	1.30 (1.19) b-d	10.1 (1.67) ab	10.1 (1.67) ab
T_{11}: T_1 + Vermicompost 1.25 t ha^{-1}	1.31 (1.22) de	1.25 (1.11) c-e	10.1 (1.67) ab	8.13 (1.00) b
T_{12}: T_1 + Vermicompost 2.5 t ha^{-1}	1.22 (1.00) ef	1.08 (0.67) de	8.13 (1.00) ab	10.1 (1.67) ab
T_{13}: T_1 + FYM 2.5 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1.51 (1.51) cd	1.30 (1.19) b-d	10.1 (1.67) ab	12.1 (2.33) ab
T_{14}: T_1 + FYM 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1.43 (1.56) cd	1.43 (1.56) a-c	10.1 (1.67) ab	10.1 (1.67) ab
T_{15}: T_1 + FYM 2.5 t ha^{-1} + Vermicompost 1.25 t ha^{-1}	1.47 (1.67) cd	1.43 (1.56) a-c	10.1 (1.67) ab	10.1 (1.67) ab
T_{16}: T_1 + Gliricidia 2.5 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1.18 (0.89) ef	1.23 (1.04) c-e	8.13 (1.00) ab	8.13 (1.00) b
T_{17}: T_1 + Vermicompost 1.25 t ha^{-1} + Gliricidia 2.5 t ha^{-1}	1.07 (0.67) f	1.07 (0.67) de	8.13 (1.00) ab	8.13 (1.00) b
T_{18}: T_1 + Vermicompost 1.25 t ha^{-1} + Pongamia 2.5 t ha^{-1}	1.13 (0.78) ef	0.82 (0.19) f	8.13 (1.00) ab	8.13 (1.00) b
T_{19}: Cotton sole crop (100 % RDF and FYM)	-	-	12.1 (2.33) a	12.1 (2.33) ab
T_{20}: Soybean sole crop (100 % RDF and FYM)	1.84 (2.89) a	1.60 (2.07) a	-	-
Mean	**1.44**	**1.35**	**9.58**	**9.72**
S.E.M	**0.06**	**0.07**	**1.76**	**1.49**
C.V. (%)	**7.93**	**9.53**	**20.5**	**24.5**

Figures in the parenthesis indicate original values and analyzed data are $\sqrt{x + 05}$ *values; Means followed by the same letters do not differ significantly (0.05) by DMRT; RC – Recommended Check; DAS – Days after sowing*

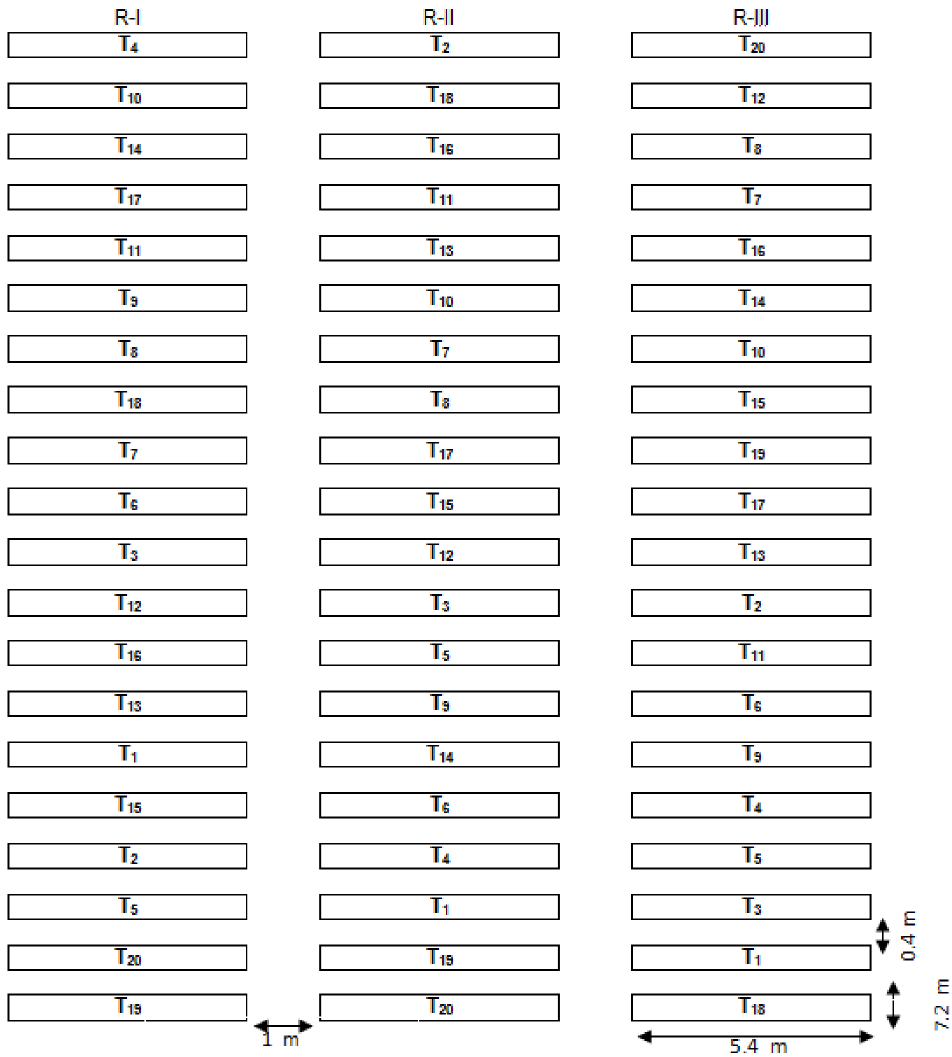

Fig. 1. Plan of layout for integrated nutrient management to sustain productivity of Bt cotton + soybean intercropping system

4. CONCLUSION

In cotton and soybean intercropping system, application of 100% RDF for both cotton and soybean + Vermicompost 1.25 t ha^{-1} + Gliricidia (or pongamia) 2.5 t ha^{-1} produced an ability to withstand against leaf reddening, insect pests and diseases for sustainable production of the system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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