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Increased water use efficiency for higher yield and quality in guava under rainfed conditions through *in situ* soil moisture conservation

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ABSTRACT

Field experiments were conducted to standardize *in situ* soil and moisture conservation measures in rainfed guava production. Mulching with polythene enhanced soil moisture (upto 111%) and the impact was much visible for longer periods (160 days) after cessation of rainfall. Further, higher soil organic carbon built up (from 0.68 to 0.92 % O.C. over a period of three years) was observed with polythene mulching. It was also reflected in the nitrogen content of the soil which increased from 109.4 to 354.8 kg/ha during three years period. Polythene mulching with raised soil around the root zone showed 39.8 % higher fruit yield in guava over control on three years pooled mean basis. The treatment recorded 12.30 t/ha at sixth year of guava planting. Mulching with polythene although recorded slightly lower gross returns (Rs.6,19,870/ha), recorded higher benefit cost ratio (1:5.25) and was followed by mulching with enriched coir pith (1: 4.83).

Key words: *Psidium guajava*, enriched coir pith, polythene mulching, rainfed, soil organic carbon.

INTRODUCTION

Guava (*Psidium guajava L.,*) is a popular fruit crop of India among the common mass as is visible through the increasing area in the recent past (from 0.236 m. ha in 2012-13 to 0.261 m.ha during 2017-18 as per advance estimates 2017-18 (NHB, 2) owing to its suitability for different situations of cultivation and early and stable returns. The crop responds to availability of moisture both in terms of number and size of the fruits. Availability of nutrient and water are of practical significance for improving the production and productivity of guava. These two inputs are essentially required to be managed in a manner which provides maximum output. Inadequacy of one or other nutrients at critical stage of fruit development, adversely affect the productivity and quality of produce (Singh and Singh, 14).

Standardisation of rainfed production technology for guava assumes practical significance in the wake of its vast potential. A strategy that ensures acceptable use of the available resources presumes that the limited resources are efficiently used so that the benefits per unit out put are optimized. Guava crop that is imposed to varying levels of moisture may show diverse responses in terms of effect of water stress on plants at physiological, biochemical and molecular levels and these three response levels according to the severity and timing of the water stress (Critchley and Siegert, 8).

Mulching is an useful practice to protect the roots of the crop plants from heat and cold so as to moderate the micro climate in the root zone and create congenial condition for the growth. Reduction in salinity and weed control, decisive effects on earliness, improved yield and quality of the crop are the other advantages of mulching. Mulching can be practiced in fruit crops like guava using crop residues and other organic material available in the farm. It aids in efficient soil and moisture conservation, weed suppression and maintenance of soil structure, improved yield and quality (Bhardwaj, 6). Mulches are known to improve the use efficiency of applied nutrients and use of reflective mulches are likely to minimize the incidence of virus diseases. Now a day's application of black plastic mulch film is becoming popular and very good results have been achieved particularly in arid and semi-arid regions (Bhardwaj, 5). Black polyethylene film (100 micron thick) is also known to help in conservation of moisture and increase root growth, flowering and fruiting and minimize fruit drop with enhancement in yield.

Thus, mulching can bring an effective change in increasing horticultural crop production in water scarcity regions. Therefore, this study was aimed to assess the impact of *in situ* soil and moisture conservation measures in enhancing the utilization of rainfall and improve the productivity for better economic feasibility under rainfed conditions in guava.

MATERIALS AND METHODS

Field experiments were conducted during 2015 to 2018 at ICAR-Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru located at a

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latitude of 13°8'12"N and a longitude of 77°29'45"E. The present experiment was conducted in four years old guava (variety Arka Kiran) spaced at 4m × 4m. The maximum temperature during the experimental period ranged from 24°C to 36°C and the minimum temperature ranged between 10°C to 22°C. The average relative humidity was higher during September and October months. Mean rainfall of the region is 850mm. The organic carbon content of the soil was fairly moderate (0.68 %).

The experiment was conducted in RBD design with four replications. There were five different *in situ* moisture conservation treatments. The treatments included velvet bean (*Mucuna pruriens*) as live mulch in the basins (T_1), enriched coir pith mulching (T_2), placement of coconut husk beneath the soil surface (T_3), polythene mulching in the basins (T_4) with farmers practice of ring and basin as control (T_5). Live mulch of *Mucuna* was established in the basins of guava during rainy season and was cut and applied as a dried mulch after the cessation of the rainfall. The raw coir waste was enriched with Arka Microbial Consortium (AMC) and was applied to a depth of 10 cm. Half splits of tender coconut were incorporated in the root zone to a depth of 30cm for the treatment T_3. Polythene mulch of 100 gsm was applied over raised basins with few holes for infiltration of rain water. Farmer's practice of ring and basin was kept as control for comparison. The treatments were imposed from June 2015 onwards. During the experimental period for three years, an amount of 978.3 mm, 877.9 mm, 462.8 mm rainfall was received.

The crop was managed with recommended package of practices purely under rainfed conditions. The mulches were applied as per the treatments in the raised basins prepared covering the effective root zone of the crop each year during onset of monsoon. The fruits harvested from each of the treatment was quantified periodically and total fruit yield was estimated. Except for yield, the mean results for each of the parameters of all the three years have been pooled.

RESULTS AND DISCUSSION

The pooled mean results of the field trial for three years during the period 2015 to 2018 are presented and discussed here:

All the *in situ* soil moisture conservation treatments differed significantly from the control by 35 days after cessation of rainfall and the impact of it was much visible for longer periods (160 days) after cessation of rainfall (Fig. 1). On a pooled mean basis, mulching with polythene recorded 111 % more moisture in top 30 cm soil differing significantly from the control (no mulching) indicating its superiority in conserving the soil moisture *in situ*. The increase in soil moisture under polythene mulching was to an extent of 94% to 198 % over the control during 35 days to 160 days after cessation of rainfall. It was followed by coir pith mulching which recorded a mean increase of 86.7 per cent in soil moisture over the control. Higher moisture conservation in the soil through mulching may be attributed to modification of favourable micro-climatic conditions in soil. When soil surface is covered with organic mulch, it helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. Higher soil moisture with polythene mulching may be attributed to the conservation of surface soil with protection from the direct sunlight. Better soil

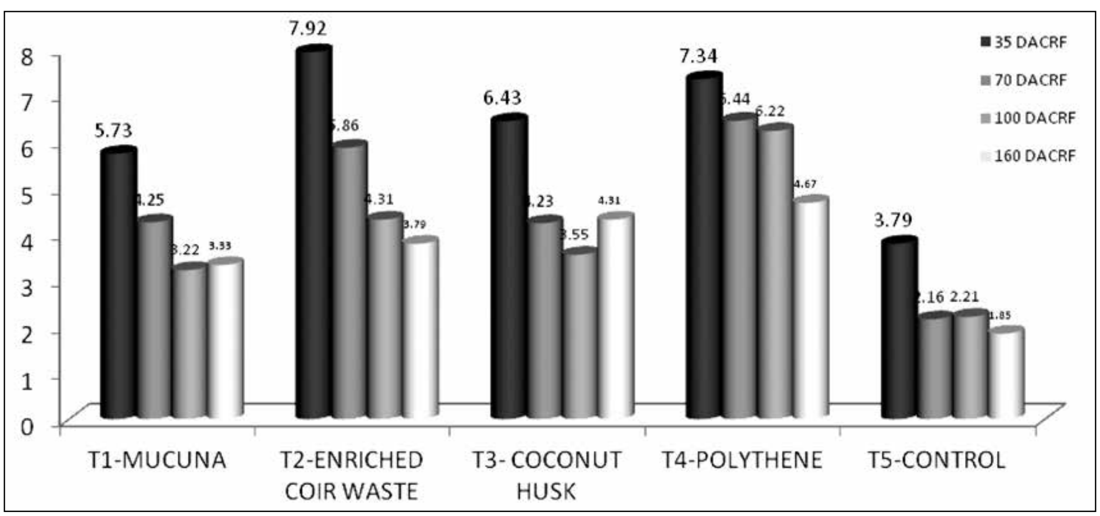

Fig. 1. Soil moisture content (%) as influenced by *in situ* rain water conservation practices during different periods after cessation of rainfall.

moisture in enriched coir pith may also be attributed to the higher pore space for *in situ* storage of rain water. Khurshid *et al.* (9) opined that mulch cover reduces surface run-off giving more opportunity time for rainwater infiltration into the soil. Chen and Katan (8) observed high water content in the top 5 cm of soil (an increase of 4.7 % in clayey, 3.1 % in loamy and 0.8–1.8 % in sandy soil) with polythene mulch. Further Purohit *et al*. (13) observed that use of polyethylene mulch in the field increased the soil temperature especially in early spring, reduced weed problems, increased moisture conservation, reduced certain insect pest population, recorded higher crop yield with more efficient use of soil nutrients.

Requirements of guava for mineral nutrients differ from other crops and is related with its perennial nature, flushing and fruiting behaviour and desired quality of fruits. Soil is major source of nutrients and availability of nutrients to plants for its function is determined by various associated factors and root system. Major concentration of guava roots is observed in surface soil upto 25 cm depth and horizontally upto 100 to 150 cm. The activity of root depends upon soil moisture and fruit load (Singh and Singh, 14).

Soil fertility in general improved with different *in situ* moisture conservation treatments. Mulching guava basins with polythene not only moderated the soil pH from 5.30 to 5.55 but also enhanced the organic carbon from 0.68 to 0.92 % over a period of three years The same was also reflected in the nitrogen content of the soil which increased from 109.4 to 151.0 kg/ha during the period. The increase in organic carbon built up with polythene mulching may be attributed to the impact of soil and moisture conservation in the treatment owing to covering of the surface soil. Further, the increased moisture and moderated temperature with mulching also favoured higher microbial activity inturn improving the soil fertility (Table 1). The impact of polythene mulching was also observed with potassium built up in soil from 170 to 365 kg/ha. This may be attributed to the fact that mulches modify hydrothermal regime, recycle plant nutrients, promote crop development and increase yields. The mineral nitrogen content of soil i.e. ammonical and nitrate nitrogen are greatly affected by mulching and higher doses of nitrogen fertilization (Bhagat *et al*., 4). Mulch protects the surface of the soil against unfavorable factors, reduces nutrient leaching and improves growing conditions (Baumann *et al*., 3; Kolota and Adamczewska-Sowiñska, 10). Further, Acharya and Sharma (1) and Muhammad *et al.* (11) observed that mulched treatments show significantly greater total uptake of nitrogen, phosphorus and potassium than corresponding un-mulched ones.

Microbial growth in general affected significantly with different mulching treatments. Polythene mulching recorded significantly higher population of bacteria (7.3×10^6 cfu /g of soil), fungi (13.0×10^4 cfu /g of soil) and P solubilizers (21×10^5 cfu /g of soil). Whereas live mulch with *Mucuna* recorded significantly higher population of actinomycetes (6.3×10^4 cfu /g of soil); zinc solubilizers were found significantly higher (13×10^4 cfu /g of soil) with placement of coconut husk (Table 2). Although free N fixers were not significantly influenced by the mulching treatments, relatively higher (8×10^4 cfu/g of soil) population was observed with polythene mulching which may be attributed to conservation of soil moisture for longer duration. Similar observations of statistically higher microbial population with mulching was observed by Bhagat *et al*., (4).

The mean number of fruits per plant in guava varied significantly among the *in situ* soil moisture conservation practices (Table 3). Except for live

Table 1. Soil fertility parameters as influenced by different *in situ* soil moisture conservation treatments.

Soil fertility parameter	T_1		T_2		T_3		T_4		T_5		Initial level (2015)
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	
Soil pH	6.13	5.83	6.32	5.28	5.98	5.44	5.80	5.55	6.45	4.81	5.30
E.C (dS m^{-1})	0.82	0.17	0. 42	0.20	0.44	0.16	1.13	0.26	0.55	0.49	0.14
Organic Carbon (%)	0.67	0.18	0.17	0.23	0.60	0.69	0.98	0.92	0.81	0.51	0.68
N (kg/ha)	239.9	29.7	60.1	37.1	216.5	113.9	354.8	151.0	95.8	84.2	109.4
P (kg/ha)	70.0	18.8	46.8	27.1	83.5	16.5	95.8	36.8	74.4	31.1	36.42
K (kg/ha)	692.6	616.3	616.1	542.5	725.6	911.3	1130.6	365.0	959.2	421.3	170.0

T_1 : *Mucuna* live mulch
T_2 : Enriched coir pith application
T_3 : Placement of coconut husk beneath the soil surface
T_4 : Polythene mulching in the basins
T_5 : Ring and basin (control)

Table 2. Microbial population as influenced by different *in situ* soil moisture conservation treatments in guava.

Treatments	General microbial population			Beneficial microbial population		
	Bacteria (10^6 cfu/g of soil)	Fungi (10^4 cfu /g of soil)	Actinomycetes (10^4 cfu/g soil)	Free-N fixers (10^4 cfu/g soil)	PSB (10^5 cfu / g of soil)	Zinc solubilizers (10^4 cfu/g soil)
Mucuna live mulch	2.7	0.9	6.3	4.0	8.7	6.3
Enriched coir pith application	2.8	1.7	4.7	2.7	2.3	5.3
Placement of coconut husk beneath the soil surface	3.9	9.2	2.3	6.3	2.6	13.0
Polythene mulching in the basins	7.3	13.0	0.3	8.0	21.0	8.3
Ring and basin (control)	2.7	0.9	1.3	5.6	1.7	3.0
S.Em ±	0.78	1.01	1.14	1.44	1.60	1.10
C.D.(P=0.05)	2.47	3.24	3.65	NS	5.10	3.50

Table 3. Guava yield as influenced by *in situ* soil moisture conservation treatments (pooled mean of 2015-18).

Treatments	No. of fruits/ plant				Fruit yield (kg/plant)				Fruit yield (t/ha)				Mean fruit weight (g)
	2015-16	2016-17	2017-18	Mean	2015-16	2016-17	2017-18	Mean	2015-16	2016-17	2017-18	Mean	
Mucuna live mulch	102.8	148.1	116.0	122.3	8.4	12.4	7.7	8.7	5.2	6.2	4.8	5.4	131.8
Enriched coir pith application	323.5	247.3	220.3	263.8	21.9	12.3	15.5	18.7	13.6	11.8	9.7	11.6	172.1
Placement of coconut husk	267.0	253.8	265.0	262.0	17.9	11.8	21.1	20.1	11.2	13.2	13.2	12.5	208.0
Polythene mulching in the basins	208.7	314.3	212.5	245.2	14.7	11.7	20.2	19.7	9.2	15.2	12.6	12.3	183.0
Control	172.3	217.3	118.8	169.8	14.1	11.9	9.5	12.9	8.8	9.5	6.0	8.1	145.0
S. Em+	41.9	40.4	43.94	16.3	3.1	0.4	3.5	3.7	2.0	2.1	2.2	0.7	14.5
C.D. (P=0.05)	130.7	NS	NS	50.8	NS	NS	10.6	1.2	NS	NS	6.6	2.3	43.0

mulching of *Mucuna*, significantly higher number of fruits were recorded with other mulching treatments as compared to the control (169.8/plant). Although enriched coir pith application recorded significantly higher number of fruits (263.8/plant), it was at par with placement of coconut husk (262/ plant) as well as with polythene mulching (245.2/ plant).The lower fruit number with live mulching may be attributed to the competition of *Mucuna* in the root zone although it was grown only during rainy season and was cut and applied as a dried mulch during rest of the season suggesting it is not worthy. On the contrary, higher fruit number with coir pith mulching was due to the enhanced soil moisture in the root zone. Singh *et al*. (15) also recorded higher fruit number, fruit weight and fruit yield with black polyethylene mulching. Maximum water saving (47.52%) was recorded through drip irrigation and polyethylene mulching as compared to control (unmulched basin irrigation).

The mean fruit yield per plant and fruit yield (t/ha) over three years followed a similar trend as that of mean fruit number. Although highest fruit yield (12.5 t/ha) was recorded with placement of coconut husk, it was at par with enriched coir pith mulching (11.6 t/ha) as well as with polythene mulching (12.3 t/ha). The increase in fruit yield with these treatments was in the range of 43.1 % to 54.3 %. Polythene mulching with raised soil around the root zone showed 39.8 % higher fruit yield in guava over control on three years pooled mean basis. The treatment recorded 12.30 t/ha at sixth year of guava planting. Application of enriched coir pith recorded overall yield advantage of 31.8 %. Borthakur and Bhattacharyya (7) observed effect of mulching and found significantly higher yield of guava (13.6 kg/ plant) as compared to control (8.7 kg/plant). Patra *et al*. (12) studied the effects of mulching on the growth and fruit yield of guava (cv. Sardar) and reported that the plants under black polythene mulch produced maximum yield (44.3 kg/plant and 12.32 t/ha).

Table 4. Economics of *in situ* soil moisture conservation treatments in rainfed guava (pooled mean of 2015-18).

Treatments	Apportioned initial cost (Rs/ha)	Actual cost of cultivation (Rs/ha)	Treatment cost (Rs/ha)	Total cost (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C Ratio
Mucuna live mulch	28,260	71,770	2,700	1,02,720	3,24000	2,21,280	2.15
Enriched coir pith application	28,260	71,770	19,350	1,19,370	6,96,000	5,76,630	4.83
Placement of coconut husk	282,60	71,770	30,980	1,31,010	7,50,000	6,18,990	4.72
Polythene mulching in the basins	28,260	71,770	18,110	1,18,130	7,38,000	6,19,870	5.25
Control	28,260	71,770	0.00	1,00,020	5,28,000	4,27,980	4.28

The fruit size was significantly higher (208 g) with placement of coir husk compared to the control (145 g) which however was at par both with polythene mulching (183 g) and coir pith application (172.1g). Further, the mean fruit weight was reduced by 10% with coir pith application (131.8 g) as compared to the control.

The pooled mean economic analysis in guava indicated that although the gross returns were higher with placement of coconut husk (Rs.7,50,000/ha), the cost of cultivation was also relatively higher (Rs.1,31,010/ha) leading to moderate net returns (Rs.6,18,990/ha). However, polythene mulching although recorded slightly lower gross returns (Rs.7,38,000/ha), recorded higher net returns (Rs.6,19,870/ha) with better benefit cost ratio (1:5.25). It was followed by mulching with enriched coir pith (Rs.5,76,630 net returns /ha and 1: 4.83 benefit cost ratio) (Table 4). The superiority of polythene mulching may be attributed to the cumulative impact of the treatment leading to enhanced soil and moisture conservation coupled with soil fertility improvement overall leading to higher productivity, net returns and benefit cost ratio.

Thus, the results of the study have clearly indicated the benficial effects of polythene mulching for rainfed guava production to conserve the soil moisture for longer periods, enhance the yield and sustain the soil fertility. Rainfed production of guava using the polythene mulch was also found practically more remunerative.

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