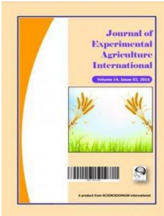

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Influence of *In-situ* Soil Water Conservation Practices on Growth, Yield and Economics of Large Cardamom under Rainfed Condition at North East India

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Authors' contributions

This work was carried out in collaboration between all authors. Authors BAG and TB designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors Subhash Babu and ABA reviewed the experimental design and all drafts of the manuscript. Authors SSB and KD managed the analyses of the study. Authors Sreekrishna Bhat and RS performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was carried out during 2015-2016 in rainfed condition at Indian Cardamom Research Institution (ICRI), Regional Research Station, Spices Board Research farm at Kabi, North Sikkim, India. The experiment was laid out in a Randomized Block Design, with eight treatments *viz.,* T_1 (trench across the slope), T_2 (trench across the slope + biomass in trench), T_3 (pit in between four plants), T_4 (pit in between four plants + biomass in the pit), T_5 (half moon-shaped trench at the base of every clump), T_6 (half moon-shaped trench + biomass in trench), T_7 (surface mulching) and T_8 (control) with three replications. In respect of growth parameters of large

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cardamom significantly higher number of immature tillers (5.63 & 5.62), mature tillers (5.40 & 5.42) and vegetative buds (5.59) were recorded in trenches across slope filled with biomass followed by treatment half-moon shape trench at base of every clump. Highest number of spike/clump (4.62), capsule/spike (8.34), dry yield/clump (57.92 gm), dry yield (257.42 kg/ha) yield parameters were found in the treatment having trench across slope filled with biomass, followed by treatment having half-moon shape trench at base of every clump as compare to control. Among the soil moisture conservation practices, surface mulching recorded significantly higher values of soil moisture *i.e.* 23.15, 22.96, 24.26, 23.00 and 23.72 per cent on 30th November, 31st December, 31st January, 29th February and 31st March, respectively. The treatment trench across the slope+ biomass in slope gave maximum net (₹2, 81,009/-) and gross return (₹4, 11,099/-), as well as benefit: Cost ratio (2.16), followed by half-moon shape trench at base of every clump, when compared with the control.

Keywords: In-situ soil water; yield; economics; large cardamom; rainfed condition.

1. INTRODUCTION

Large cardamom (*Amomum subulatum* Roxburgh) belonging to family Zingiberaceae is the most important spice crop of Sikkim Himalayan region. It is also cultivated economically in some other northeastern hill states like Arunachal Pradesh and Nagaland. Nepal, Bhutan and Myanmar are the other three countries where large cardamom is cultivated [1,2,3]. It is a perennial crop grown in tracks with well distributed rainfall spread around 200 days with a total of about 3000-3500 mm/year. The crop cannot thrive well under water stress conditions and is grown up to 1000 to 2200 m amsl [4]. Large cardamom is a shallow rooted crop and frequent irrigation required during dry period (October to March). It is essentially a cross-pollinated crop due to the heterostylic nature of its flowers though they are self-fertile. Effective cross pollination occurs with the help of bumble bees *(Bombus breviceps* and *B. haemorrhoidalis* Smith) [5]. It is a shade loves plant (sciophyte), usually grows under tree canopy and requires well distributed rainfall round the year [6,7]. Sikkim state of India is the largest producer of large cardamom and constitutes lion share of Indian and world market. Sikkim alone contributes 50 per cent of the world's production of large cardamom [8,9]. In India it was used as early as the 6th century BC in Ayurvedic preparations [10,11]. It is used as a spice and also in several Ayurvedic preparations. It contains 2-3 per cent essential oils having stomachic, diuretic and cardiac stimulant properties and is also a remedy for throat and respiratory trouble [12]. Majority of large cardamom grown in rainfed conditions and average state productivity is 230-250 kg/ha.

In recent years, productivity of large cardamom declined in Sikkim. There are several factors responsible for decline in productivity which can be overcome by providing suitable location specific technological interventions [13]. The production and productivity may increase many fold if proper scientific production technology is adopted in the region. The North Eastern Region of India known for its high rainfall suffers from severe water scarcity during major parts of the year from November to March. Because of this, fields remain fallow during this period; particularly under terrace and upland condition, where scope of growing crops with stored water is limited. The main reason for its low productivity is its cultivation in rainfed conditions. Owing to this constraint the crop faces severe moisture stress during winter period. Under such situation farmers have to depend largely on rain and in situ soil water conservation practices. To increase moisture availability to the plantation crops, it is necessary to adopt *in-situ* water conservation techniques with application of organic mulches. The principle behind the different practices is to increase infiltration by reducing the rate of runoff; temporarily impounding water on surface soil to increase opportunity time for infiltration and modifying the land configuration for inter plot water harvesting [14]. For improving growth and productivity of rainfed large cardamom under changing climatic scenario the conservation and utilization of rain water is of utmost important which require efficient soil moisture conservation practices. The rain water harvesting techniques; like full moon, half moon, trench systems and pit between four plants and combined with different kind of mulch, (organic mulch) will help moisture conservation during critical stages of crop growth and development under rainfed condition. Moisture being the most limiting for growth and development in these lands, it needs to be conserved to the best advantage of crop plants [15]. [16] have observed higher soil moisture content due to compartment bunding, while [17] reported similar views due to adoption of tied ridges, furrows and compartment bunding as compared to flat bed method. In the rainfed region, water harvesting is considered among the excellent methods for productivity enhancement in fruit crops.

Organic mulches are derived from plant and animal materials; such as straw, hay, shade tree leaves, compost, sawdust, wood chips, shavings, dried weeds and animal manures. Organic mulch are efficient in reduction of nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity [18]. Organic mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil. Mulching reduces soil temperature in summer, raises it in winter and prevents the extremes of temperatures. 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. As excessive rainfall is shed drained the root zone, nutrients loss due to leaching is reduced. Organic mulches return organic matter and plant nutrients to the soil and improve physical, chemical and biological properties of soil after decomposition; which in turn increases crop yield. Soil under the mulch remains loose, friable and leading to suitable environment for root penetration. Organic mulch not only conserves soil moisture, but also increases soil nutrients through organic matter addition [19]. In large cardamom soil organic mulches helps in reducing water erosion; retain moisture content in soil for longer time and play very important role in growth and development from October to March months of dry period [20].

Conservation of *in-situ* soil water still holds more relevance in large cardamom plant, which is less resistant to moisture deficit environment than traditional drought resistant agricultural crops. Hence, successful attempt was made to grow large cardamom exclusively under rainfed condition with *in-situ* water conservation practices.

2. MATERIALS AND METHODS

'In the present investigation, attempt has been made to evaluate influence of *in-situ* soil water conservation practices on growth and productivity of large cardamom under rainfed condition at North East India. Field experiment was carried out during 2011-2016 in rainfed conditions at Indian Cardamom Research Institute (ICRI), Regional Research Station, Spices Board research farm at Kabi. It is located at 27° 24' N latitude, 88° 37' E longitudes and altitude of 1594 m amsl. Soil of experimental field was clay loam and had soil pH of 4.1 (1:2.5 soil/ water ratio), 251.3 kg/ha alkaline permanganate oxidizable N, 29.10 kg/ha Brays P1, 202.7 kg 1 N ammonium acetate exchangeable K and 1.95 per cent organic carbon. Large cardamom cultivar *Sawney* was selected and planted at a spacing of 1.5 m x 1.5 m in July 2011. The experiment was laid out in a Randomized Block Design, comprised of eight treatments *viz.*, T_1 (trench across the slope), T_2 (trench across the slope + biomass in trench), T_3 (pit in between four plants), T_4 (pit in between four plants + biomass in the pit), T_5 (half moon-shaped trench at the base of every clump), T_6 (half moon-shaped trench + biomass in trench), T_7 (surface mulching) and T_8 (control) with three replications. Six plants in each treatment per replication were selected for the study. The treatments were imposed during September. In trench system, trench was created up stream side 30 cm away from the plant. The shape and design of the structure was 30 cm deep, 30 cm width and 10 m length of trench created for collection of runoff water. In pit system, pit was opened with size of 30 cm × 30 cm in between four large cardamom plants for soil moisture conservation. In half moon system- semi circular bunds were created at downstream side of the plant. The shape and design of the structure was semi circular bunds having 30 cm width and 30 cm high at a radius of 30 cm away from large cardamom plant for storage of runoff water from catchment area. In surface mulching, local mulch shade trees dried leaves materials were used as 15 cm thick cover which was approximately 100 kg per plot. The experimental farm falls under temperate region having cold condition from November to February. The plants were given uniform cultural treatment (Recommended organic package of practices) during course of investigation. In Sikkim region November to March is dry period (generally no rainfall received). Total rainfall received from April 2015 to March 2016 was 4598 mm out of which 548 mm rainfall was received during November 2015 to March 2016 with 28 numbers of rainy days (Figs. 1 and 2). The growth observations were recorded two times in the year *viz.*, September 2015 and March 2016. Observations were recorded on large cardamom number of immature tillers, mature tillers, vegetative buds, capsule / clump,

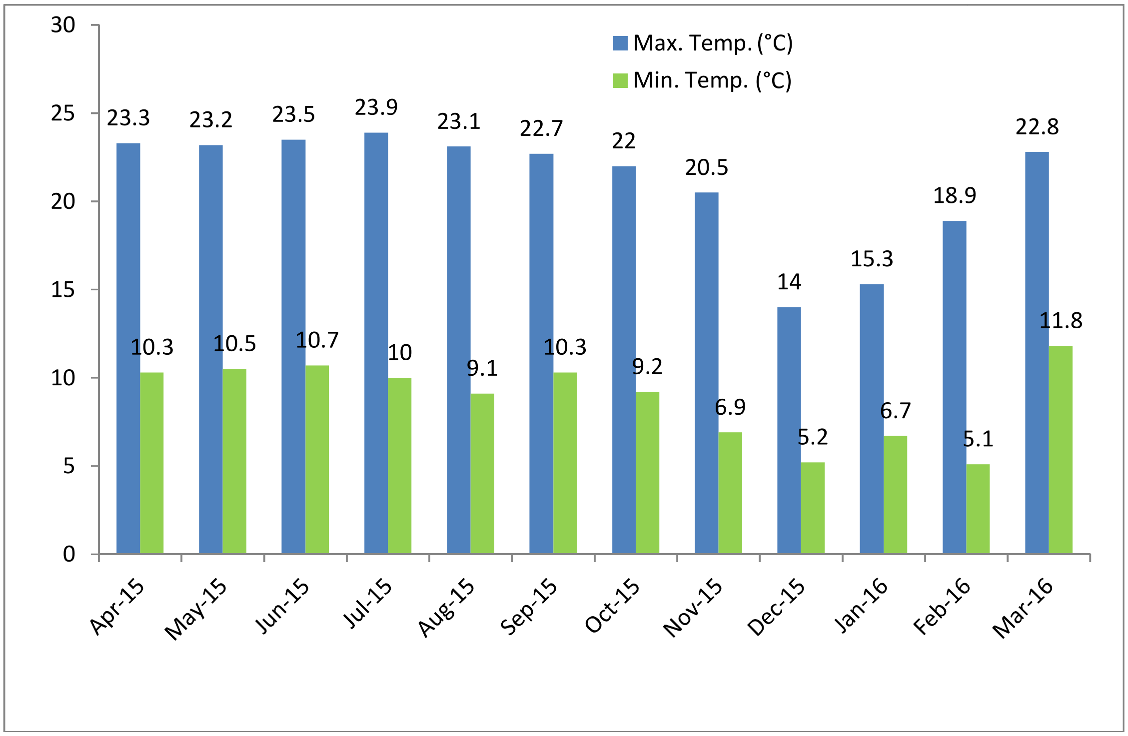

Fig. 1. Graphical presentation of monthly maximum and minimum temperature (°C) from April-2015 to March 2016

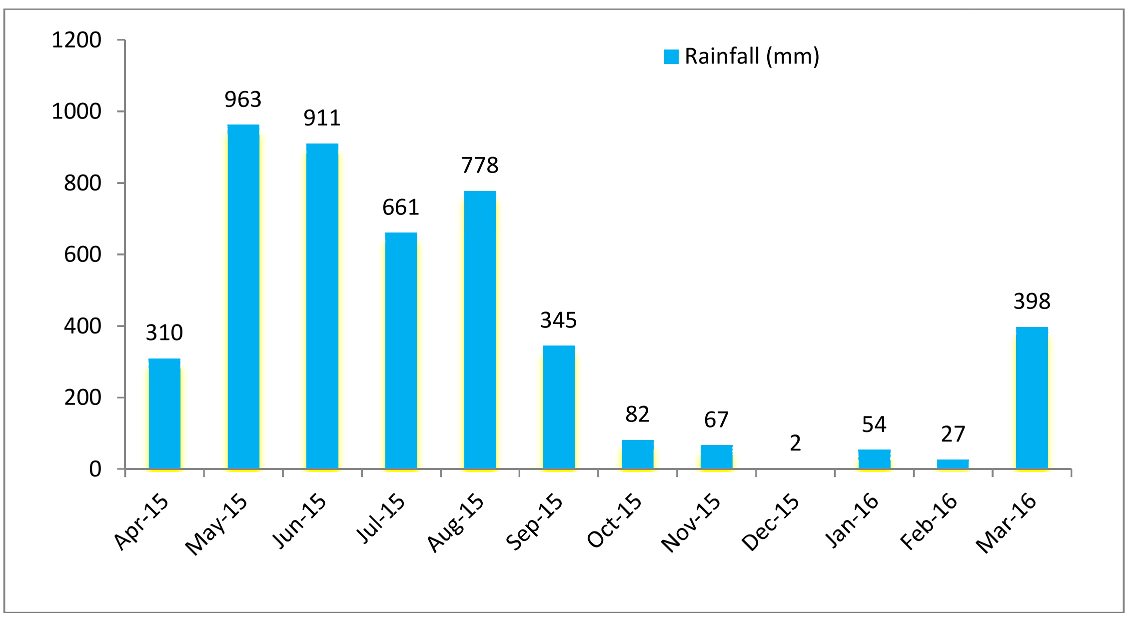

Fig. 2. Graphical presentation of monthly average rainfall (mm) received from April-2015 to March 2016

dry yield / clump, dry yield / ha and soil moisture status at different intervals. After the end of monsoonal rainfall in September, monthly soil moisture in 0-15 cm soil profile was recorded from November, 2015 to March, 2016 in each treatment. Periodical observation on soil moisture status in rhizosphere zone was recorded at monthly intervals. Soil moisture contents were recorded monthly intervals from 0-15 cm depths by thermo- gravimetric method [21]. Soil samples taken were obtained as indicated above in tight moisture cans and kept in shade to avoid evaporation water losses. Moist samples were weighed and dried in an oven for 24 hours at 105°C temperature. The ratio of weight loss in drying to dry weight of soil multiplied by 100 gives the soil moisture percentage (Δw). The soil moisture percentage was calculated by following formula.

$$\Delta w = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

Data were analyzed statistically for interpretation of results and drawing conclusions [22].

3. RESULTS AND DISCUSSION

3.1 Growth and Yield Parameters of Large Cardamom

Critical appraisal of data revealed that change in land configuration with respect to *in-situ* soil water conservation practice had resulted in considerable variation in growth and yield parameters of large cardamom (Table 1). Significantly higher numbers of immature tillers (5.63 & 5.62) were found in trenches across slope filled with biomass, followed by treatment half-moon shape trench at base of every clump (5.58 & 5.60). Maximum numbers of mature tillers (5.40 & 5.42) were recorded in trenches across slopes filled with biomass followed by treatment having treatment half-moon shape trench at base of every clump (5.37 & 5.36) as compare to control. In respect of vegetative buds the treatment having trench across slope filled with biomass recorded highest number of vegetative buds (5.59), followed by treatment having half-moon shape trench at base of every clump (5.51). In respect of yield parameters of large cardamom recorded maximum number of spike/clump (4.62) in treatment having trench across slope filled with biomass followed by treatment Surface mulching (4.53) as compare to control. Maximum number of capsule/spike (8.34) recorded in treatment trench across slope filled with biomass followed by treatment Half-moon shape trench at base of every clump (8.13). Highest dry yield/clump (57.92 gm) observed in treatment having trench across slope filled with biomass followed by treatment Surface mulching (54.29 gm). Maximum dry yield (257.42 kg/ha) recorded in the treatment having trench across the slope filled with biomass followed by treatment having half-moon shape trench at base of every clump (245.40 kg/ha) as compare to control.

3.2 Soil Moisture Content

With respect to soil moisture content, results showed that all the soil moisture conservation practices were significant when compared with the control (Table 2). Among the soil moisture conservation practices, surface mulching recorded significantly higher values of soil moisture *i.e.* 23.15, 22.96, 24.26, 23.00 and 23.72 per cent on 30th November, 31st December, 31st January, 29th February and 31st March, respectively. This study indicated that surface mulching conserved higher soil moisture compared with the control. Surface mulching reduces percolation, evaporation losses; provide more opportunity for absorption of water by soil. Similar results were also reported by previous researcher in large cardamom [23].

3.3 Economics of Large Cardamom

The economics of large cardamom were significantly influenced by the different *in-situ* soil water conservation practices (Table 4). The highest costs involved in treatment Pit in between four plants + biomass in pit (₹ 1, 32,000/-), followed by treatment Trench across the slope+ biomass in slope (₹ 1, 30,000/-) and treatment Pit in between four plants (₹ 1, 30,000/-). Among the different *in-situ* soil moisture conservation practices Pit in between four plants + biomass in pit was the costliest one and it was 5.31 per cent higher than the control treatment. The treatment trench across the slope+ biomass in slope gave maximum net (₹ 2, 81,009/-) and gross return (₹ 4, 11,099/-), as well as benefit: cost ratio (2.16), followed by half-moon shape trench at base of every clump as compare to control. Thus, the trench across the slope+ biomass in slope resulted in higher net benefit: cost ratio and a better choice to realize maximum benefit to the farming community. Our field experimentation clearly demonstrated the significant influence of *in-situ* soil water conservation practices on growth, yield and economics of large cardamom under rainfed condition at North East India.

Table 1. Effect of *in-situ* soil water conservation practices on growth parameters of large cardamom at Kabi North Sikkim, India

Treatment	Immature tillers / clump (nos.)		Mature tillers / clump (nos.)		Vegetative buds/clump (nos.)
	Sep 2015	Mar 2016	Mar 2016	Sep 2015	Mar 2016
T_1-Trench across the slope	5.06	5.08	5.05	5.05	5.09
T_2-Trench across the slope+ biomass in slope	5.63	5.62	5.40	5.42	5.59
T_3-Pit in between four plants	5.29	5.31	5.15	5.13	4.81
T_4-Pit in between four plants + biomass in pit	5.52	5.54	4.85	4.87	4.92
T_5-Half-moon shape trench at base of every clump	5.58	5.60	5.37	5.36	5.51
T_6-Half-moon shape trench + biomass in trench	5.44	5.42	5.23	5.25	5.47
T_7-Surface mulching	5.16	5.13	5.20	5.21	5.22
T_8-Control	4.25	4.29	3.79	3.88	4.10
SEm±	0.18	0.10	0.16	0.19	0.14
LSD (P=0.05)	0.55	0.32	0.49	0.58	0.44

Table 2. Effect of *in-situ* soil water conservation practices on yield parameters of large cardamom at Kabi North Sikkim, India during September, 2015

Treatment	Spike /clump (nos.)	Capsule /spike (nos.)	Dry yield /clump (gm)	Dry yield (kg/ha)
T_1-Trench across the slope	3.72	7.54	53.71	238.48
T_2-Trench across the slope+ biomass in slope	4.62	8.34	57.92	257.42
T_3-Pit in between four plants	4.10	7.93	53.26	236.38
T_4-Pit in between four plants + biomass in pit	3.67	6.85	50.79	225.45
T_5-Half-moon shape trench at base of every clump	3.88	8.13	55.34	245.40
T_6-Half-moon shape trench + biomass in trench	4.22	7.40	50.37	223.29
T_7-Surface mulching	4.53	7.31	54.29	241.24
T_8-Control	3.41	6.10	47.23	209.15
SEm±	0.21	0.17	2.24	9.80
LSD (P=0.05)	0.64	0.54	6.78	29.74

Table 3. Soil moisture status at various interval at Kabi North Sikkim, India

Treatment	Soil moisture (%)				
	30/11/2015	31/12/2015	31/01/2016	29/02/2016	31/03/2016
T_1-Trench across the slope	20.76	19.51	18.13	19.75	22.13
T_2-Trench across the slope+ biomass in slope	20.66	20.30	20.97	20.07	20.33
T_3-Pit in between four plants	21.08	19.52	21.74	20.63	21.90
T_4-Pit in between four plants + biomass in pit	21.37	22.08	22.69	21.67	23.11
T_5-Half-moon shape trench at base of every clump	21.44	19.29	18.87	20.90	22.94
T_6-Half-moon shape trench + biomass in trench	22.49	21.23	19.61	19.87	22.71
T_7-Surface mulching	23.15	22.96	24.26	23.00	23.72
T_8-Control	19.33	19.13	17.70	19.39	19.40
SEm±	2.37	1.71	2.01	1.80	2.48
LSD (P=0.05)	7.18	5.19	6.09	5.48	7.54

Table 4. Economics of large cardamom influenced by *in-situ* soil water conservation practices at Kabi North Sikkim, India

Treatment	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit: Cost ratio
T_1-Trench across the slope	1,28,000/-	3,80,852/-	2,52,852/-	1.98
T_2-Trench across the slope+ biomass in slope	1,30,000/-	4,11,099/-	2,81,009/-	2.16
T_3-Pit in between four plants	1,30,000/-	3,77,498/-	2,47,498/-	1.90
T_4-Pit in between four plants + biomass in pit	1,32,000/-	3,60,043/-	2,28,043/-	1.73
T_5-Half-moon shape trench at base of every clump	1,28,000/-	3,91,903/-	2,63,903/-	2.06
T_6-Half-moon shape trench + biomass in trench	1,29,000/-	3,56,594/-	2,27,594/-	1.76
T_7-Surface mulching	1,27,000/-	3,85,260/-	2,58,260/-	2.03
T_8-Control	1,25,000/-	3,34,012/-	2,09,012/-	1.67

(Average price of dry large cardamom in 2015 was ₹ 1597/- per kg)

4. CONCLUSION

In present scenario available soil moisture is a major problem in large cardamom growing areas in dry months. For increasing moisture availability in large cardamom soils, it is necessary to adopt *in-situ* water conservation techniques with application of organic mulches. In large cardamom significantly higher number of immature tillers, mature tillers and vegetative buds were recorded in trenches across slope filled with biomass. Highest number of spike/clump, capsule/spike, dry yield / clump (gm) and dry yield (kg/ha) were found in the treatment having trench across slope filled with biomass. In respect of soil moisture conservation, surface mulching recorded significantly higher values of soil moisture. The treatment trench across the slope+ biomass in slope gave maximum net and gross return, as well as benefit: cost ratio, followed by half-moon shape trench at base of every clump, when compared with the control.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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