Agricultural Water Management 97 (2010) 988–994

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

# Response of vanilla (*Vanilla planifolia* A.) intercropped in arecanut to irrigation and nutrition in humid tropics of India

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ARTICLE INFO

*Article history:*
Received 4 October 2009
Accepted 29 January 2010
Available online 26 February 2010

*Keywords:*
Vanilla
Intercropping
Arecanut
Irrigation
Nutrition

ABSTRACT

A 5-year field trial to assess the impact of microsprinkler irrigation and nutrition on vanilla grown as intercrop in arecanut plantation was conducted on a laterite soil. Pooled analysis indicated that microsprinkler irrigation at 1.0 Epan resulted in significantly higher green bean yield (842 kg ha$^{-1}$) than 0.75 Epan (579 kg ha$^{-1}$). Organic manure application in the form of vermicompost (720 kg ha$^{-1}$) and FYM (768 kg ha$^{-1}$) and recommended NPK (718 kg ha$^{-1}$) produced green bean yield at par with recycling of *gliricidia* prunings (625 kg ha$^{-1}$). Irrigation at 1.0 Epan proved superior by registering maximum benefit:cost (B:C) ratio of 2.25 compared to 1.62 at 0.75 Epan. The highest B:C ratio was obtained with recommended NPK (2.27) followed by recycling of *gliricidia* prunings (2.10), vermicompost (1.87), vermicompost + arecanut husk mulching (1.80) and FYM (1.64). The soil pH increased by 0.4 units in 2008 compared with the pre-experimental soil pH of 5.6 in 2004. Nutrition alone and in combination with irrigation had significant impact on soil pH. Organic manure application increased the soil pH (6.1–6.2) significantly over recommended NPK (5.6) at the end of experiment in 2008. Significant variation in soil organic carbon (SOC) was noticed due to different nutrition treatments. Application of vermicompost and FYM significantly increased the SOC content by 38–54% in 2008 over initial levels in 2004. Bray's P availability was influenced by nutrition and its interaction with irrigation. Application of FYM continuously for 4 years has resulted in significant increase in Bray's P content (41.3 mg kg$^{-1}$) compared to other nutrition treatments (9.4–17.2 mg kg$^{-1}$). Irrigation equivalent to 0.75 Epan (223 mg kg$^{-1}$) increased the K availability significantly over 1.0 Epan (172 mg kg$^{-1}$). The K availability was significantly higher in recommended NPK (416 mg kg$^{-1}$) than in other organic treatments (98–223 mg kg$^{-1}$) at 0–30 cm soil depth. Overall, vanilla responded well to irrigation and nutrition in arecanut-based cropping system with a better economic output and improved soil fertility.



## 1. Introduction

Vanilla (*Vanilla planifolia* Andrews.) is a perennial tropical orchid with succulent stem, sessile leaves and aerial adventitious roots at the nodes. This climbing orchid is indigenous to Mexico and West Indies for more than two centuries and the introduction of this plant to other regions was not possible because absence of specific pollinating agents. The amenability of this crop to vegetative propagation and artificial pollination paved the way for commercial cultivation of vanilla in other countries. Vanilla can be grown in humid tropics from sea level up to an altitude of 1500 m and optimum temperature range is 21–32 °C. The major vanilla growing areas are Madagascar, Mexico, Comoros Islands, Reunion Island, Uganda, Java, Philippines, Papua New Guinea, Fiji, Jamaica and Costa Rica (Reismunandar and Sukma, 2002) and parts of Peninsular India (GOI, 2008). Vanilla is a natural alternative to synthetic vanillin and is the second most expensive spice traded in the world market. The principal commercial source of vanillin ($C_8H_8O_3$) is the bean of *Vanilla planifolia* (Purseglove et al., 1981), which has medicinal uses (Jenna, 2005).

Global cultivation of vanilla is estimated to be 82,098 ha with a production of 9080 tonnes and productivity of 110 kg ha$^{-1}$ (FAO, 2008). Indonesia and Madagascar are the major producers of vanilla and contribute 90% of the world production. USA is the biggest consumer of vanilla followed by Germany, France, Canada, Australia and Japan. In the international market, the demand for natural vanillin is increasing at 7–10% per annum as a result of global movement to return to natural products. Spices board has taken initiative to propagate and popularize vanilla cultivation in India as this crop has export potential in the global market. In India, the area under vanilla cultivation was 2545 ha in 2002–2003 with a production of 92 tonnes (IISR, 2005). In a span of 5 years, the area under vanilla increased sharply to 5129 ha with a production of 233 tonnes as per 2006–2007 statistics (GOI, 2008). Estimates suggest that the requirement of vanilla cured beans in India would be

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0378-3774/$ – see front matter 
doi:10.1016/j.agwat.2010.01.031

about 935 tonnes if 10% of the synthetic vanillin is to be replaced with natural vanillin (NABARD, 2004).

Vanilla cultivation is one of the most attractive propositions as it fetches remunerative price (George, 1984). However, there are some specific bottlenecks in vanilla cultivation such as inadequate research, narrow germplasm base, pollination and diseases (Shanmugavelu et al., 2002; Sudheer et al., 2007). Vanilla requires partial shade (Dressler, 1981) and support. A special system of trailing is required to facilitate induction of flowering and promotion of vegetative growth. When vine attains a height of 1.5 m, the after growth has to be trailed downwards very close to the ground leaving a gap of 30 cm and again coiled up like a loose loop. The main drawback in vanilla cultivation is absence of natural pollination as stigma is physically prevented from coming in contact with anther by a flap like structure known as rostellum (Bory et al., 2008). For commercial production of vanilla beans, it is essential to hand pollinate the flowers (Crane and Walker, 1984). Vanilla comes to flowering in 3rd year of planting. The crop needs moisture stress during December to February for flowering and high humidity during March to May for proper bean development.

Vanilla can be successfully cultivated in coffee, banana, lemon, grape fruit, orange and pine production systems (Santosa et al., 2005; Castro and Franco, 2007). It is a suitable intercrop for coconut and arecanut in India (Madhusoodanan and Radhakrishnan, 2001; IISR, 2005; Nybe and Miniraj, 2007). Importance of vanilla as one of the component crops in coconut production system was highlighted by Nybe et al. (2004). It is reported that vanilla cultivation in coconut is economically feasible if irrigation is provided in low rainfall areas (Nybe and Miniraj, 2007). In India, vanilla is predominantly cultivated as an intercrop in arecanut plantations. However, systematic studies on input requirement of vanilla are completely lacking. The constraints in arecanut growing tract in West coast of India are emphasized by Bhat et al. (2007) and Bhat and Sujatha (2009). Arecanut is predominantly cultivated in laterite soils, which have inherent constraints like P fixation, rapid hydraulic conductivity, high infiltration rate, leaching of basic cations and low CEC (3–15 cmole $kg^{-1}$). Deficiency of K was reported in laterite soils of Karnataka (Badrinath et al., 1998).

There is a need to improve the productivity of vanilla through proper input management. The right combination of water and nutrients is a prerequisite for higher yields and good quality produce. Likewise, there is a need for organic farming approach for production of good quality beans and to ensure better price to farmers. The most important factors that determine the proper development of the vanilla pods in vanilla-orange production system are: nutrition, moisture, temperature and pollination (Ariadna et al., 2009). Vanilla requires regular irrigation and nutrition to support its growth and yield due to shallow root system and succulent nature of above ground growth. Microsprinkler irrigation with provision for overhead misting of water would be ideal for maintaining high humidity during summer and for wetting entire foliage of vanilla. Soil application of organics (50% N as FYM/vermicompost + 50% N as deoiled cakes + 50% P as bone meal + 50% K as wood ash + bio-fertilizers) was found effective compared to recommended inorganic NPK fertilizers in increasing the yield and quality of the beans of vanilla (Sadanandan and Hamza, 2006). After reviewing the work on nutrition of vanilla, Nybe and Miniraj (2007) opined that 1% foliar spray of 17:17:17 NPK and application of biogas slurry and groundnut oil cake are ideal for vanilla. The review also suggested that vanilla yield can be enhanced by soil application of 20:10:30 g of NPK per vine per year and foliar application of urea, SSP and MOP at the rate of 1.0, 0.5 and 1.5%, respectively in January, May and September. Arecanut plantation generates 7.4 tonnes organic waste biomass and 1.7–2.0 tonnes of husk per hectare per year. These wastes have limited uses and recycling of biomass in the form of vermicompost is a better option (Chowdappa et al., 1999). With this background, the present study was contemplated to develop a strategy for water and organic nutrition of vanilla by utilizing recyclable organic wastes available locally in order to lower production costs.

## 2. Materials and methods

### 2.1. Site, climate and soil characteristics

The field experiment was conducted during June 2004 to December 2008 at Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, India (12° 15′N latitude and 75° 25′E longitude, 91 m above MSL). The climate of the experimental site is humid tropical with mean annual rainfall of 3670 mm and 120 rainy days. The annual rainfall varied from 3188 to 3778 mm during experimental period. Mean temperature ranges from 21 °C (minimum) to 36 °C (maximum). The average relative humidity varies between 61 and 94%. The weather data of the experimental location for 5 years (2004, 2005, 2006, 2007 and 2008) is shown in Fig. 1. The soil of the experimental site is sandy clay loam (laterite) with a pH of 5.6, 1.91% organic carbon, 3.6 mg $kg^{-1}$ P and 111 mg $kg^{-1}$ K at 0–30 cm soil depth. The soil is a well drained deep laterite comprising 54.6% sand, 14.4% silt and 36% clay at 0–60 cm soil depth. The bulk density of soil is 1.61 g $cm^{-3}$ and field capacity varies between 18 and 22% at different depths.

### 2.2. Treatment details

The arecanut plantation was established in September, 1997 at a spacing of 2.7 m × 2.7 m. A field plot size of 3324 $m^2$ was selected. *Gliricidia* standards were planted in June, 2004 at spacing of 2.7 m × 2.0 m in inter-rows of arecanut. Tissue cultured vanilla plantlets of 50 cm length were utilized for planting. Vanilla was planted in small pits of 20 $cm^3$ dug at 25 cm distance from the *Gliricidia* pole. Each subplot comprised of 8 vanilla vines, which accounted for 64.8 $m^2$ area. The experiment was laid out in Split-plot design with three replications. Main plots comprised of three irrigation levels, viz., 0.5, 0.75 and 1.0 of pan evaporation (Epan). Sub plots included five nutrition treatments, viz., $T_1$ - recommended fertilizer (60:17:83 kg N:P:K $ha^{-1}$), $T_2$ - vermicompost on N equivalent basis, $T_3$ - vermicompost on N equivalent basis + arecanut husk mulching, $T_4$ - FYM on N equivalent basis and $T_5$ - recycling of *gliricidia* punings to vanilla. Arecanut husk was applied to vanilla at 2 kg per vine per year as mulch after vermicompost application in $T_3$.

Irrigation scheduling was done based on pan evaporation data (Epan). The evaporation data was collected from USWB Class A open pan evaporimeter of meteorological observatory situated 100 m away from the experimental site. Reference crop evapotranspiration ($ET_0$) was calculated on daily basis using modified Penman method (Doorenbos and Pruitt, 1977). The actual evapotranspiration was estimated by multiplying reference evapotranspiration with crop coefficient values. Vanilla is a surface feeder with succulent vegetative growth. Besides, the laterite soils have poor moisture retention capacity. Thus, it is necessary to maintain soil moisture at field capacity level (18–22%). After considering climatic, crop and soil factors, it was assumed that $ET_c$ for vanilla is equivalent to $ET_0$. Irrigation efficiency of 85% was considered for microsprinkler irrigation. Daily water requirement of vanilla was estimated by multiplying pan evaporation with plant spacing, crop canopy constant and crop coefficient values. The estimated crop canopy constant values for calculating water requirement of vanilla were 0.2–0.3 during different stages. Arecanut invariably needs irrigation during December–May and the plantation was irrigated through drip system. In this trial, there was a need to provide

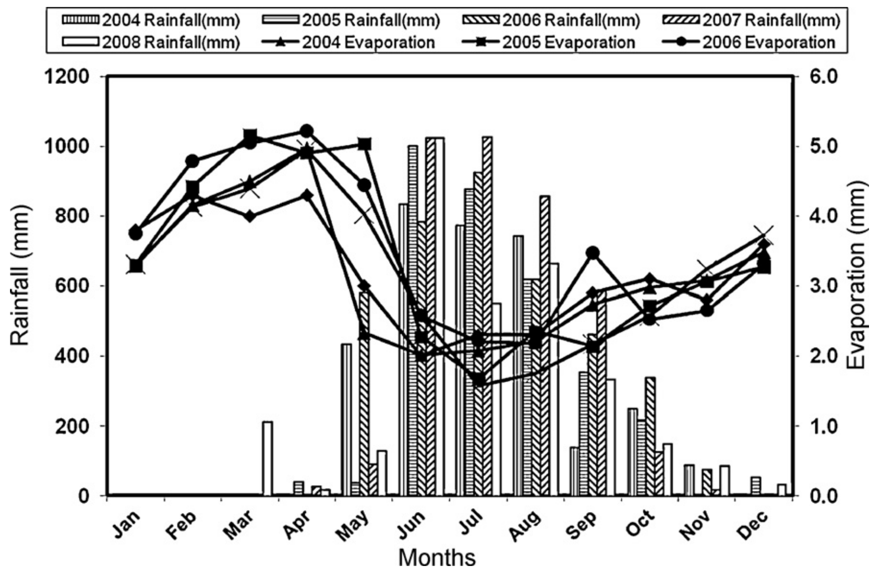


**Fig. 1.** Month wise rainfall and evaporation data during 2004–2008.

separate irrigation system to vanilla as it needs dry period of 2 months during November to January for flowering followed by wetting of entire foliage during bean development stage. The aerial roots and leaves of vanilla also absorb moisture. For this, misting of water would be appropriate to wet entire foliage. Micro-sprinklers of 110 L h$^{-1}$ discharge rate were fixed on 20 mm rigid PVC pipes of 6 ft height. Separate valves on each lateral line were used to control different irrigation levels.

The nutrient content in FYM was estimated as 0.5% N, 0.12% P and 0.45% K. Vermicompost contained 2% N, 0.6% P and 0.9% K. The nutrient content in *gliricidia* was estimated as 2.5% N, 0.15% P and 1.6% K. Arecanut husk was applied at 2 kg per vine per year as mulch and it contained 1.22% N, 0.15% P and 1.64% K. Arecanut husk has limited uses and is used as organic mulch for better root growth in vanilla. Arecanut husk acts as an insulator for the surface feeding roots of vanilla from adverse weather conditions. Organic wastes from arecanut garden were converted in to vermicompost using *Eudrilus euginae* and recycled back to vanilla. *Gliricidia* standards were maintained through regular pruning in all vines. Pruned biomass was weighed and recycled back to the vanilla in $T_5$, i.e., recycling of *gliricidia*. Standard recommended practices were followed for arecanut. Fruit rot incidence caused by *Phytopthora palmivora* is generally noticed in arecanut during monsoon season. Spraying of 1% Bordeaux Mixture (BM) was done for control of this disease. Copper oxychloride (0.2%) was sprayed to control stem rot noticed in few vines in vanilla in 2008.

### 2.3. Soil and organic manure analysis

Soil samples were collected at 0–30 cm depth from basins of four vines in each treatment before and at the end of experimentation. Samples were air dried, ground and sieved through a 2 mm screen. Soil samples were analysed for pH, organic carbon, available P and K using standard procedures (Jackson, 1973). Soil pH was measured in 1:2 soil water suspension. Soil organic carbon was measured by Walkley and Black method. Available P was estimated by ascorbic acid reductant method for colour development after extraction with Bray's reagent. Available K was estimated using ammonium acetate extraction method. The samples of FYM, vermicompost, arecanut husk and *gliricidia* were analysed for major nutrients every year before treatment application. The nutrient content was averaged over years and expressed as %. Total N in organic manures was determined using micro-Kjeldahl method (Jackson, 1973). The samples were digested in a 1:3 perchloric–nitric acid mixture for total P and K estimation. Phosphorus (vanadomolybdate) and potassium (flame photometry) were determined following Piper (1966).

### 2.4. Growth, yield and economics

Total length of the vine was measured during first year of planting. When the vines attained a height of 150 cm, the vine was trailed downwards very close to the ground leaving a gap of 30 cm and again coiled up like a loose loop. Flowering was initiated in February 2007, i.e., in 3rd year of planting and manual pollination was done daily from 0600 to 1200 h for 22 days. Pollination was done in 10–12 flowers in each inflorescence. In 2008, flowering was initiated in March and pollination was done for 20 days.

Pods take about 8–9 months to attain maturity. The beans of vanilla were harvested when pods were slightly yellow. For computation of yield of vanilla, the fresh beans were harvested during November to December every year and expressed as kg per hectare of arecanut plantation. Based on length, the beans were graded into first (>15 cm long), second (10–15 cm) and third (<10 cm). Ripe nuts of arecanut were harvested during October–March every year, sun dried, dehusked and expressed as kg dry kernel per hectare. Local market and farm gate rates were considered for computing net returns. The price of green vanilla beans per kg in the local market was Rs. 140, 100 and 70 for first, second and third grade beans, respectively. For estimating benefit:cost ratio (B:C ratio), total cash outflows were divided by total cash inflows during experimental period. Statistical analysis was done using standard analysis of variance (ANOVA) technique.

## 3. Results and discussion

### 3.1. Growth parameters of vanilla

In first year, the growth of vanilla in terms of length of vine and number of leaves was more or less uniform among all treatments (Fig. 2). The length of vanilla vine increased from 0.66 m in October 2004 to 3.09 m in July 2005. Similarly, the number of leaves increased from 19 to 54 during the same period. First coiling of vines started in second year and flowering was initiated in third year in all vines irrespective of treatments.

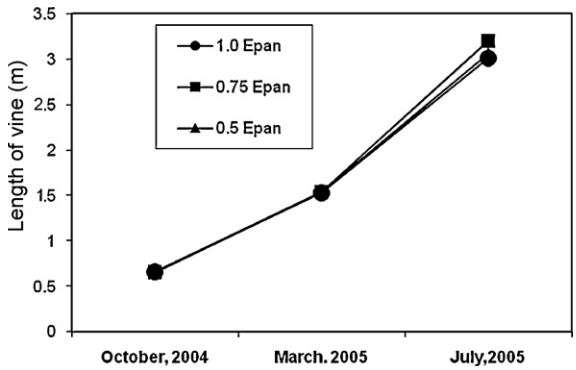


**Fig. 2.** Influence of irrigation on initial length of vine of vanilla in first year.

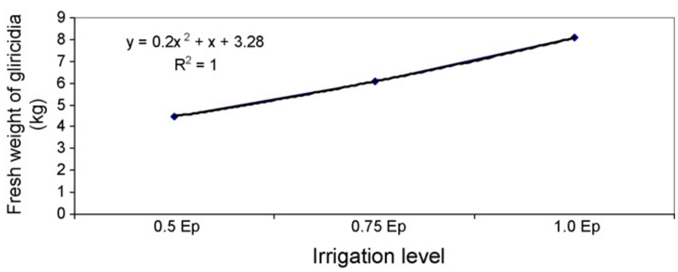


**Fig. 3.** Pruned biomass of *gliricidia* recycled (kg vine$^{-1}$) to vanilla in treatment 5 (mean of 4 years).

### 3.2. Recycled biomass of gliricidia

The biomass of *gliricidia* recycled per vine per year is shown Fig. 3. Irrigation treatments significantly influenced pruned biomass of *gliricidia* in $T_5$, i.e., recycling of *gliricidia* prunings to vanilla. Irrigation at 1.0 Epan level registered maximum pruned biomass of *gliricidia* (8.08 kg vine$^{-1}$) followed by 0.75 Epan (6.08 kg vine$^{-1}$). The pruned biomass of *gliricidia* contained 2.5% N, 0.15% P and 1.6% K. This indicates that the biomass of *gliricidia* recycled at 1.0 Epan irrigation level can meet N, P and K requirement of vanilla. Further, the *gliricidia* was pruned and applied thrice in a year, which ensured nutrient supply at different stages. Generally, vanilla is trained on the arecanut palm itself by the farmers or the vines are trained by providing trellis in between arecanut palms. However, this practice interferes with management of arecanut and damages vanilla vines caused by falling arecanut leaves. The results suggest that it would be appropriate to train vanilla on living standards like *gliricidia* to ensure *in situ* recycling of biomass and to obtain better yields and income.

### 3.3. Green bean yield of vanilla

The green bean yield of vanilla as influenced by irrigation and nutrition is presented in Table 1. The vines started wilting at 0.5 Epan irrigation level in May 2007, i.e., during pod development stage of vanilla. Though vanilla sustained at lower irrigation level of 0.5 Epan during vegetative stage for first 3 years, the same was not sufficient during yielding stage. This suggests that vanilla needs irrigation level of more than 0.5 Epan during summer. In view of failure of one irrigation level, the pooled analysis of bean yield was done using only two main plots. Pooled analysis of 2-year data showed significant influence of irrigation on bean yield of vanilla (Table 1). Nutrition treatments and interaction between irrigation and nutrition had no significant effect on bean yield of vanilla. Microsprinkler irrigation at 1.0 Epan resulted in significantly higher green bean yield (842 kg ha$^{-1}$) than 0.75 Epan (579 kg ha$^{-1}$). Higher yields at 1.0 Epan irrigation might be due to congenial humidity and higher fruit survival in summer season. Castro and Franco (2007) also stated that water and environmental relative humidity are important for fruit survival in vanilla. Increase in microclimatic humidity due to sprinkler irrigation is reported in arecanut plantation (Bhat and Sujatha, 2004). The results suggest that irrigation is most important for vanilla in summer season, i.e., during March–May as it is a surface feeder.

Organic manure application in the form of vermicompost (720 kg ha$^{-1}$) and FYM (768 kg ha$^{-1}$) and recommended NPK (718 kg ha$^{-1}$) produced green bean yield at par with recycling of *gliricidia* prunings (625 kg ha$^{-1}$). These results revealed that recycling of *gliricidia* prunings can sustain the yield levels at par with those obtained using recommended NPK, vermicompost and FYM. This can be attributed to slow and regular availability of nutrients in this treatment as *gliricidia* was recycled thrice in a year.

In 2007, the green bean yield of vanilla was significantly influenced due to irrigation and nutrition. Irrigation level of 1.0 Epan (1266 kg ha$^{-1}$) was significantly superior to 0.75 Epan (864 kg ha$^{-1}$) and 0.5 Epan (497 kg ha$^{-1}$). With respect to nutrition treatments, the trend was different from pooled data of 2 years. Vermicompost + arecanut husk mulching (947 kg ha$^{-1}$), FYM (932 kg ha$^{-1}$) and recommended NPK (929 kg ha$^{-1}$) registered significantly higher bean yield than vermicompost (799 kg ha$^{-1}$) and recycling of *gliricidia* prunings (771 kg ha$^{-1}$).

When yield data of vanilla was analyzed over two main plots (0.75 and 1.0 Epan) in 2007, irrigation and nutrition

**Table 1**
Green bean yield of vanilla and B:C ratio as influenced by microsprinkler irrigation and nutrition in different years.

| | Green bean yield (kg ha$^{-1}$) | | | | B:C ratio |
|---|---|---|---|---|---|
| | 2007 | 2007[a] | 2008 | Pooled | |
| Irrigation (I) | | | | | |
| 0.5 Epan | 497 | – | – | – | – |
| 0.75 Epan | 864 | 864 | 293 | 579 | 1.62 |
| 1.0 Epan | 1266 | 1266 | 417 | 842 | 2.25 |
| LSD (0.05) | 100.4 | 73.1 | NS | 127.9 | – |
| Nutrition (N) | | | | | |
| Recommended NPK (60:17:83 kg ha$^{-1}$) | 929 | 1076 | 360 | 718 | 2.27 |
| Vermicompost on N equivalent basis | 799 | 981 | 459 | 720 | 1.87 |
| Vermicompost (100% N) + arecanut husk mulching | 947 | 1132 | 308 | 720 | 1.80 |
| FYM N equivalent basis | 932 | 1175 | 361 | 768 | 1.64 |
| Recycling of *gliricidia* prunings | 771 | 960 | 290 | 625 | 2.10 |
| LSD (0.05) | 124.6 | 140.4 | 150 | NS | – |
| LSD (0.05) for interaction (I × N) | NS | NS | NS | NS | – |

*Note*: The yield data of 0.5 Epan irrigation level was not included in 2008 due to low yield levels.
[a] 2007 yield data was analysed with two main plots for pooled analysis.

treatments significantly influenced the bean yield. Yield differences among nutrition treatments, viz., FYM (1175 kg ha$^{-1}$), vermicompost + arecanut husk mulching (1132 kg ha$^{-1}$) and recommended NPK (1076 kg ha$^{-1}$) were non-significant. Production of first grade quality beans was more with vermicompost (45%) as compared to FYM (25%). The yields noticed with vermicompost (980 kg ha$^{-1}$) and *gliricidia* recycling (960 kg ha$^{-1}$) were comparable to recommended NPK (1076 kg ha$^{-1}$). In 2008, irrigation levels of 0.75 and 1.0 Epan were at par in terms of green bean yield. Vermicompost application on N equivalent basis produced significantly higher yield (459 kg ha$^{-1}$) than recycling of *gliricidia* prunings (290 kg ha$^{-1}$) and vermicompost + arecanut husk mulching (308 kg ha$^{-1}$). Sadanandan and Hamza (2006) also expressed that organics are effective compared to recommended inorganic NPK fertilizers in increasing the yield and quality of the beans of vanilla. Slow availability of nutrients for crop growth and improved soil physical and chemical properties might have resulted in higher yields with application of organics over inorganic fertilizers. The findings of Tisdale and Oades (1982), Haynes and Swift (1990) and Ansari (2008) support these results.

The average productivity of vanilla in India is 36 kg cured beans and 180 kg green beans per hectare (IISR, 2005). However, in this trial the average productivity was 175 kg cured beans and 876 kg green beans per hectare in the first year. Two years average yield was 134 and 667 kg cured and green beans per hectare, respectively. This suggests the scope for improving the productivity of vanilla by 271% with adoption of proper water and nutrient management in laterite soil belt of India. Even in the world scenario, the average cured bean yield is 110 kg ha$^{-1}$ which is 22% less than the yield realised in this experiment. Thus the results will have relevance to vanilla grown on light textured soils in humid tropics.

### 3.4. Economic feasibility

Cultivation of vanilla is complicated and labour intensive requiring skilled labour for hand pollination. Hand pollination in vanilla is said to represent 40% of the total cost of cultivation (Crane and Walker, 1984). The farm gate price of vermicompost and arecanut husk were considered for calculating production cost, though these organic wastes were recycled from arecanut garden. Irrigation at 1.0 Epan proved superior by registering maximum B:C ratio of 2.25 compared to 0.75 Epan (1.62). Highest B:C ratio was obtained with recommended NPK (2.27) followed by recycling of *gliricidia* prunings (2.10), vermicompost (1.87), vermicompost + arecanut husk mulching (1.80) and FYM (1.64). Due to higher cost of organic manures, B:C ratio was lower in organic treatments. The production of first grade beans accounted for 25% in recommended NPK and 23% in *gliricidia* recycling treatment. While, the percentage of second grade beans was maximum in *gliricidia* recycling (50) compared to NPK treatment (40). The results suggest that *gliricidia* recycling would be a better option than NPK application due to better quality beans and B:C ratio. If vanilla is grown with adoption of *in situ* recycling of *gliricidia*, there is scope for organic certification. This results in farmers realizing higher income as organically grown vanilla fetches premium price in the international market. Profitability of vanilla intercropping in pine forests was highlighted by Santosa et al. (2005).

### 3.5. Yield of arecanut

There is a perception among farmers that *gliricidia* standards would reduce the yield of arecanut. Thus, the impact of intercropping vanilla using *gliricidia* standards on arecanut yield was studied in this experiment. The year wise kernel yield of arecanut varied significantly between 1929 kg ha$^{-1}$ in 2007 and 4153 kg ha$^{-1}$ in 2008 (Table 2). This year wise variation was mainly due to alternate bearing habit and fruit rot problems arising from continuous and heavy rainfall and not due to intercropping vanilla using *gliricidia* standards. Arecanut was drip irrigated at 1.0 Epan. However, pooled data of 4 years showed that the kernel yield of arecanut was significantly influenced due to microsprinkler irrigation given to vanilla during March to May. The kernel yield of arecanut (kg ha$^{-1}$) was significantly higher at 1.0 Epan (3620) than at 0.5 (2826) and 0.75 (2897) Epan. This can be attributed to increase in microclimatic humidity in the garden, which is congenial for both arecanut and vanilla.

**Table 2**
Kernel yield of arecanut (kg ha$^{-1}$)as influenced microsprinkler irrigation given to vanilla in different years.

| | Pooled (2005–2008) |
|---|---|
| Year | |
| 2005 | 2826 |
| 2006 | 3548 |
| 2007 | 1929 |
| 2008 | 4153 |
| LSD (0.05) | 604.1 |
| Irrigation | |
| 0.5 Epan | 2826 |
| 0.75 Epan | 2897 |
| 1.0 Epan | 3620 |
| LSD (0.05) | 523.1 |

### 3.6. Soil pH and organic carbon (SOC)

Fig. 4 illustrates the variability in soil pH in vanilla basin as influenced by irrigation and nutrition. Overall, the soil pH increased by 0.4 units in 2008 compared to the pre-experimental soil pH of 5.6 in 2004. Irrigation had no significant impact on soil pH. However, nutrition and interaction between irrigation and nutrition had significant impact on soil pH. Among nutrition treatments, the soil pH remained same during experimental period in case of recommended NPK treatment, while it increased by 0.5–0.6 units with organic treatments. Organic manure application increased the soil pH (6.1–6.2) significantly over recommended NPK (5.6) at the end of experiment in 2008. It was stated that manuring tends to move soil pH towards neutrality (Whalen et al., 2000). There is evidence that organic residues from green and animal manures can increase the pH of acid soils and improve soil fertility by supplying nutrients for crop production (Bickelhaupt, 1989; Hue, 1992; Warren and Fonteno, 1993; Wong et al., 1998). Besides, this can also be attributed to irrigation water quality. Treder et al. (1997) and Bhat and Sujatha (2009) also noticed increase in soil pH due to irrigation

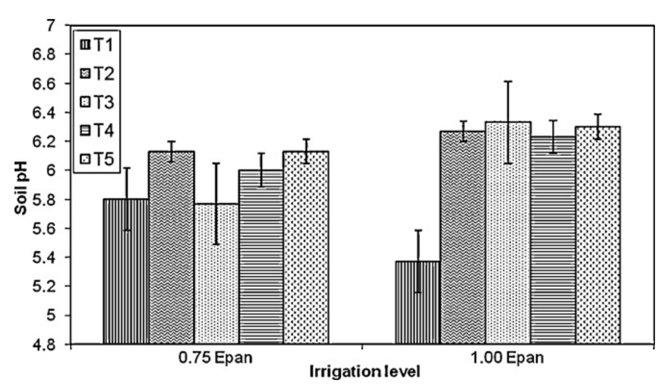


**Fig. 4.** Influence of irrigation (I) and nutrition (N) on soil pH in vanilla basin at 0–30 cm soil depth in 2008 (LSD (0.05) for I, NS; N, 0.22; I × N, 0.30; bars indicate SE of the mean). $T_1$, recommended fertilizer (60:17:83 kg N:P:K ha$^{-1}$). $T_2$, vermicompost on N equivalent basis. $T_3$, vermicompost (100% N) + arecanut husk mulching. $T_4$, FYM on N equivalent basis. $T_5$, recycling of *gliricidia* prunings.

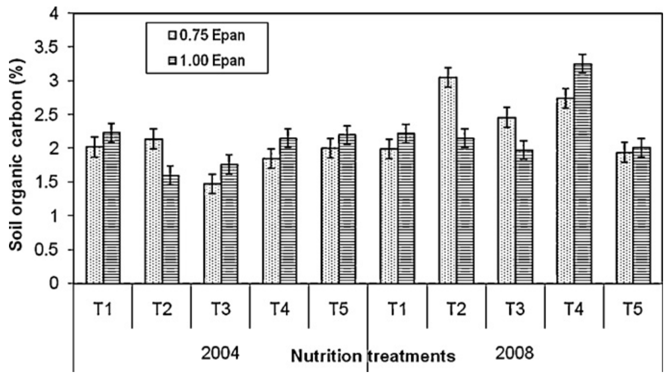


**Fig. 5.** Influence of irrigation (I) and nutrition (N) on soil organic carbon status in vanilla basin at 0–30 cm soil depth (bars indicate SE of the mean). $T_1$, recommended fertilizer (60:17:83 kg N:P:K ha$^{-1}$). $T_2$, vermicompost on N equivalent basis. $T_3$, vermicompost (100% N) + arecanut husk mulching. $T_4$, FYM on N equivalent basis. $T_5$, recycling of *gliricidia* prunings.

| | LSD (0.05) | |
|---|---|---|
| | 2004 | 2008 |
| I | NS | NS |
| N | 0.145 | 0.420 |
| I × N | 0.205 | 0.594 |
| Years | 0.329 | |

water containing a high amount of calcium and magnesium. The irrigation water in this experiment contained 6.5–20 mg kg$^{-1}$ Ca and 1.5–4.0 mg kg$^{-1}$ Mg resulting in accumulation of these nutrients in upper soil depth. Thus, increase in soil pH might be due to combined effect of irrigation and organic manure addition. The study also suggests that organic manures increase soil pH in short time and inorganic fertilizers might take long time to increase soil pH. The increase in soil pH due to application inorganic NPK through drip fertigation in arecanut in a span of 13 years was reported from this station (Bhat and Sujatha, 2009).

At 0–30 cm soil depth, soil organic carbon (SOC) content significantly increased to 2.45% in 2008 compared to initial SOC content of 1.94% in 2004 (Fig. 5). This can be attributed to application of manures. In 2004, SOC content varied significantly among nutrition treatments. Interaction between irrigation and nutrition had significant effect on SOC status. The SOC status in $T_1$, $T_4$ and $T_5$ treatments (2.00–2.12%) was significantly higher than in $T_3$ (1.61%) and $T_2$ (1.87%) treatments. However, analysis of covariance showed no significant influence of initial SOC status on the final SOC status in 2008. In 2008, significant variation in SOC was noticed due to different nutrition treatments. Application of vermicompost and FYM significantly increased the SOC content by 38–54% over initial levels in 2004. At 0.75 Epan level, the organics enriched the SOC status (2.46–3.04%) significantly over NPK (1.99%) and *gliricidia* recycling (1.94%). However at 1.0 Epan, FYM application registered significantly higher SOC over other treatments. Slight decrease in SOC from 2.10% to 1.97% was noticed in recycling of *gliricidia* pruning treatment, while it increased in other treatments. This can be attributed mainly due to application of *in situ* recycling of green biomass of *gliricidia*, which decomposes faster in tropical climate. Another reason could be presence of low percentage of lignin in immature plant tissue, which has limited capability to increase stable organic matter components. These results are substantiated by the report of Power (1990), which indicated that green manures are less effective than crop residues for stabilizing or increasing soil organic matter. Application of organic matter obtained from animal manures, crop residues and green manuring has been shown to replenish SOC (Parham et al., 2002).

### 3.7. Available soil P and K

The problem of P fixation is reported from several trials in laterite soil type (Perur, 1996; Bhat and Sujatha, 2009). However in this study, the Bray's P content was higher after 5 years (23.2 mg kg$^{-1}$) than at the initiation of experiment (3.6 mg kg$^{-1}$) at 0–30 cm depth (Table 3). Irrigation had no significant impact on P availability in 2008. However, Bray's P availability was evidently influenced due to nutrition and its interaction with irrigation. Application of FYM continuously for 4 years has resulted in significant increase in Bray's P content (41.3 mg kg$^{-1}$) compared to other nutrition treatments (9.4–17.2 mg kg$^{-1}$). The findings by Motavalli and Miles (2002) and Laboski and Lamb (2003) support these results. Nelson and Mikkelsen (2008) opined that long-term use of manures and compost as the primary N source leads to an accumulation of P in the soil.

Available K varied significantly due to irrigation and nutrition in 2008 at 0–30 cm soil depth (Table 3). Interaction effect between irrigation and nutrition was not significant. Irrigation equivalent to 0.75 Epan (223 mg kg$^{-1}$) increased the K availability significantly over 1.0 Epan (172 mg kg$^{-1}$). This might be due to higher yields at 1.0 Epan and higher uptake of K. The K availability was significantly higher in recommended NPK (416 mg kg$^{-1}$) than in other organic treatments (98–223 mg kg$^{-1}$). Among organic manure treatments, the K availability was significantly higher with vermicompost + arecanut husk mulching (223 mg kg$^{-1}$). This might be due to higher K content in arecanut husk and its slow decomposition rate. This treatment also resulted in production of higher percentage of first grade beans (48). Thus, arecanut husk can be an important source of K for organic production of vanilla. Available K was less in vermicompost treatment (98 mg kg$^{-1}$) in 2008

**Table 3**
Nutrient status at 0–30 cm soil depth in vanilla basin as influenced by microsprinkler irrigation and nutrition.

| | Bray's P (mg kg$^{-1}$) | | Available K (mg kg$^{-1}$) | |
|---|---|---|---|---|
| | 2004 | 2008 | 2004 | 2008 |
| Irrigation (I) | | | | |
| 0.5 Epan | 4.9 | – | 114 | – |
| 0.75 Epan | 1.7 | 18.6 | 121 | 224 |
| 1.0 Epan | 3.9 | 18.8 | 98 | 172 |
| LSD (0.05) | NS | NS | NS | 20.7 |
| Nutrition (N) | | | | |
| Recommended NPK (60:17:83 kg ha$^{-1}$) | 4.8 | 12.9 | 122 | 416 |
| Vermicompost on N equivalent basis | 4.2 | 17.2 | 102 | 98 |
| Vermicompost (100% N) + arecanut husk mulching | 2.8 | 9.4 | 116 | 223 |
| FYM N equivalent basis | 2.9 | 41.3 | 113 | 148 |
| Recycling of *gliricidia* prunings | 3.3 | 12.5 | 103 | 103 |
| LSD (0.05) | NS | 6.35 | NS | 43.62 |
| LSD (0.05) for interaction (I × N) | NS | 8.98 | NS | NS |

compared to its availability in 2004. This can be attributed to K removal by crop, less K in vermicompost and leaching of K in laterite soils in monsoon season. The more or less uniform nutrient status in vanilla basin due to application of different manures indicates the sufficiency of *gliricidia* recycling for vanilla to meet the crop nutrient demand. Available K in soil was maintained during experimental period in *gliricidia* recycling treatment. Thus, it might become necessary to supplement K through chemical form in later years if organic production is the requirement. Depletion of both exchangeable and non-exchangeable K was noticed with long-term organic manure application (Srivatsava et al., 2002).

## 4. Conclusions

The 5-year field experiment conducted to develop water and organic farming package to be offered to the farmers has resulted in the following conclusions.

1. Irrigation is most important for vanilla as it is a surface feeder having shallow root system and succulent above ground growth. Vanilla requires irrigation equivalent to pan evaporation for optimum yields.
2. All organic manures and recommended NPK produced bean yields at par. On the basis of yield, quality and economic feasibility, recycling of *gliricidia* prunings from standards and vermicompost application alone or in combination with husk mulching are better options for intercropped vanilla in arecanut.
3. These results also suggest that replenishment of plant-available nutrients in the form of organic or inorganic must be sustained to maintain optimum soil nutrient status.

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