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# Effect of irrigation frequency and planting method on growth, fibre yield and water use by ramie (*Boemehria nivea* L. Gaud.) in the *Indo-Gangetic* plains of West Bengal

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**ABSTRACT**

*The field experiment was conducted at Research Farm of ICAR-CRIJAF (22º452 N, 88º262 E and 9 m above MSL) located at Barrack pore, West Bengal during the year 2006 to 2008. The experiment comprised of three irrigation treatments (irrigation water/cumulative pan evaporation ratio of 0.3, 0.6 and 0.9) in the main plots and two planting methods (ridge and furrow, and flat-bed) in sub-plots to determine the effects of irrigation frequency and planting methods on fibre yield and water use efficiency (WUE) of ramie. The ramie crop receiving irrigation based on IW/CPE ratio of 0.6 recorded significantly higher leaf area index (LAI), fibre yield and WUE compared to other irrigation frequencies in all the cuttings except during the monsoon period (coinciding with 3rd and 4th cuttings). Ridge and furrow planting recorded significantly higher LAI (10.2 – 22.2%), fibre yield (7.9 - 17.2%), and WUE (25.0 – 41.0%) of ramie over flat-bed planting throughout the crop growth period. Maximum crop coefficient ($k_c$) value of ramie was recorded with 0.9 IW/CPE ratio both during pre-monsoon (0.63 - 0.94) and post-monsoon (0.88 - 0.96) periods. Similarly, flat-bed planting method recorded 14.5 to 24.5% and 17% higher $k_c$ value of ramie over ridge and furrow planting during pre-monsoon (0.57 – 0.95) and post-monsoon (0.69 – 0.88) periods, respectively.*

***Keywords* :** Crop coefficient ($k_c$), flat-bed and ridge planting, irrigation, leaf area index, ramie, water-use efficiency

Ramie (*Boehmeria nivea* L. Gaud.), commonly known as 'China Grass', is a perennial bast fibre crop belonging to *Urticaceae* family which produces one of the longest and strongest textile fibres of plant origin. Globally, ramie is cultivated in 0.052 million ha area with an annual production of 0.102 million tonnes (t) and productivity of 1.97 t ha$^{-1}$, respectively. China is the major producer contributing to about 97per cent of the world production of the fibre (http://faostat.fao.org., 2016). The crop is also grown in Brazil, Indonesia, Phillipines, Korea, Vietnam, Japan and India. However, the cultivation of the crop in India so far, is restricted in a few pocket areas like of Assam, Arunachal Pradesh, Manipur, Mizoram and Nagaland. Ramie fibre is considered as a valuable textile fibre due to its various special characteristics such as its ability to hold shape, reduce wrinkling and introduces a silky luster to the appearance of the fabric. The fibre obtained from the bark of the plant is rich in alpha-cellulose (86.9%) and contains very less amount of lignin (0.5%). Due to its unique blending property along with high tensile strength and resistance to bacterial degradation, ramie fibre is extensively used in textile sector and India imports a large quantity of ramie fibre, ramie yarn and ramie fabric every year. A well-managed ramie crop can produce 55 – 58 t ha$^{-1}$ of above- ground green biomass in 3-4 cuttings in a year under rainfed conditions (Mitra *et al.*, 2014).

The current trends indicate an increasing gap between the demand and supply of fresh water to the agricultural crops in the Indo Gangetic Plains which is affecting the stability of the sector. In view of the limited water resources of the country, proper scheduling of irrigation, therefore, becomes very important for higher economic yield as well as increased water use efficiency of the crops. Maximum grain yield of pigeon pea was recorded with irrigation based on 0.8 IW/CPE ratio (Kumbhar *et al.*, 2015) while Singh *et al.* (2014) observed that maximum seed yield of mustard was recorded in northern India when irrigation was scheduled to the crop at 0.7 IW/CPE ratio. Ramie being perennial in nature, faces water-deficit stress during pre-monsoon (March-May) and post-monsoon (October – December) period, and provision of irrigation during this period certainly improves the growth and fibre yield of the crop (Mitra *et al.*, 2014).

Planting pattern also plays an important role in improving grain yield and water-use efficiency (WUE) of the crops. The grain yield as well as WUE of both summer maize (*Zea mays* L.) and winter wheat was found to be significantly influenced by planting pattern in northern India (Naresh *et al.*, 2012). Similarly, furrow planting significantly increased winter wheat grain yield and WUE of winter wheat under water deficit conditions

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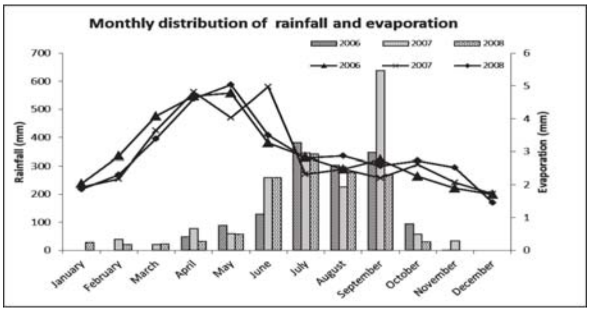
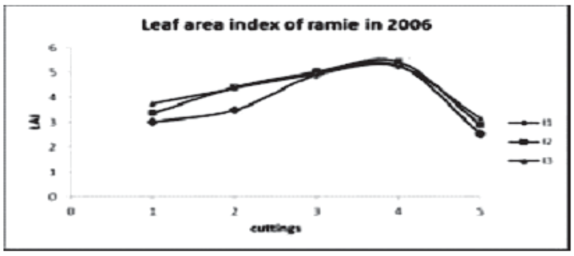
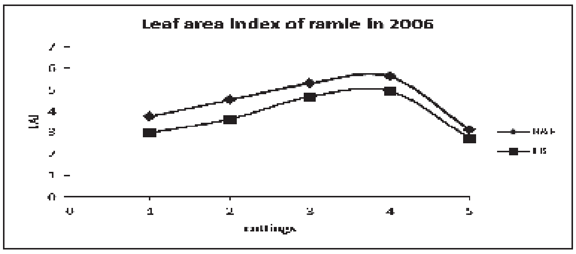


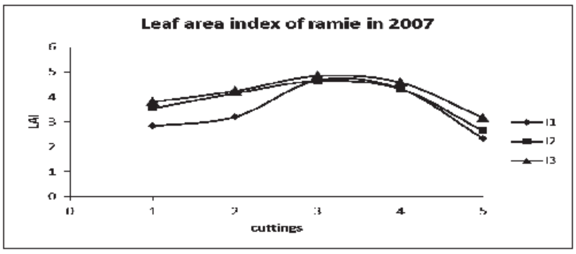

**Fig. 1: Monthly distribution of rainfall and evaporation at Barrackpore, India**



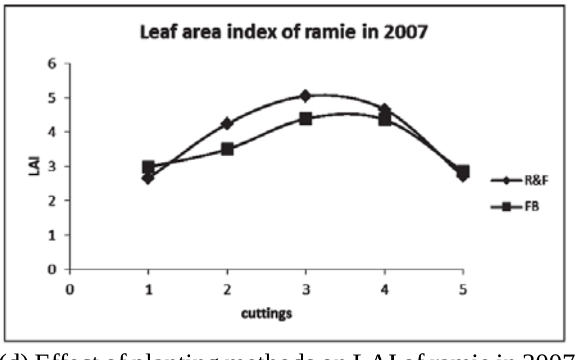

(a) Effect of irrigation on LAI of ramie in 2006



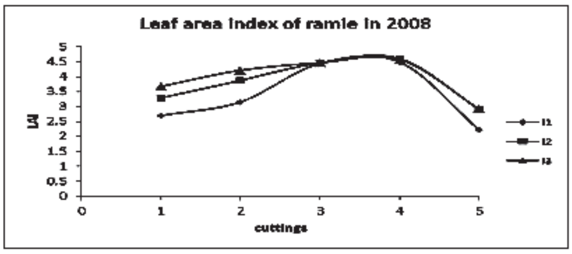

(b) Effect of planting methods on LAI of ramie in 2006



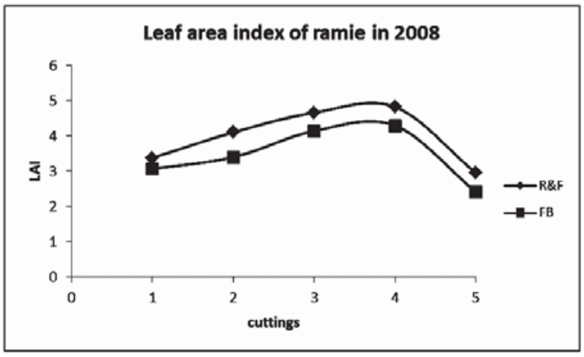

(c) Effect of irrigation on LAI of ramie in 2007



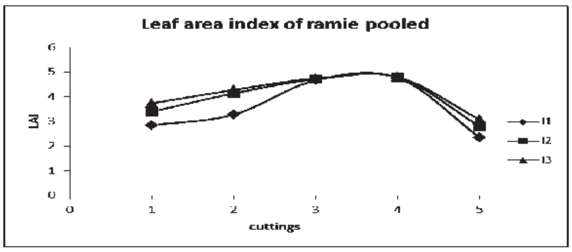

(d) Effect of planting methods on LAI of ramie in 2007



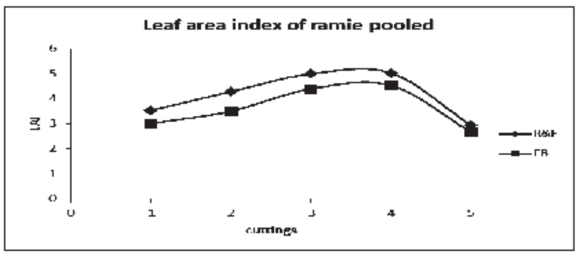

(e) Effect of irrigation on LAI of ramie in 2008




(f) Effect of planting methods on LAI of ramie in 2008

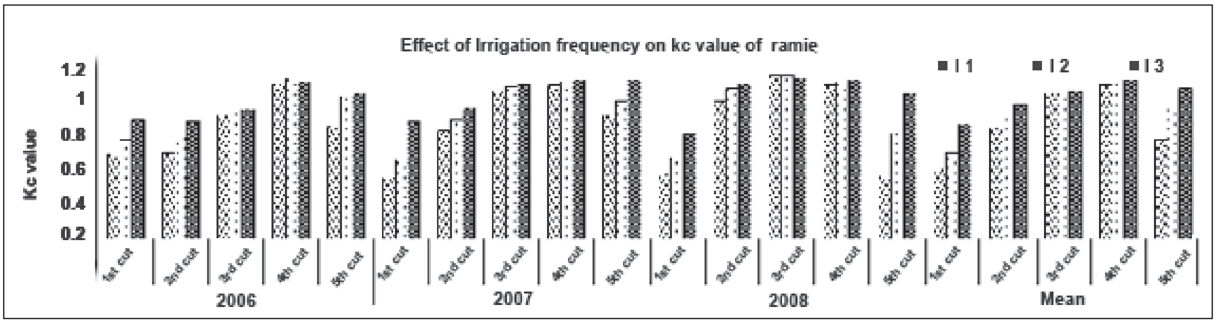



(g) Effect of irrigation on LAI of ramie (pooled)

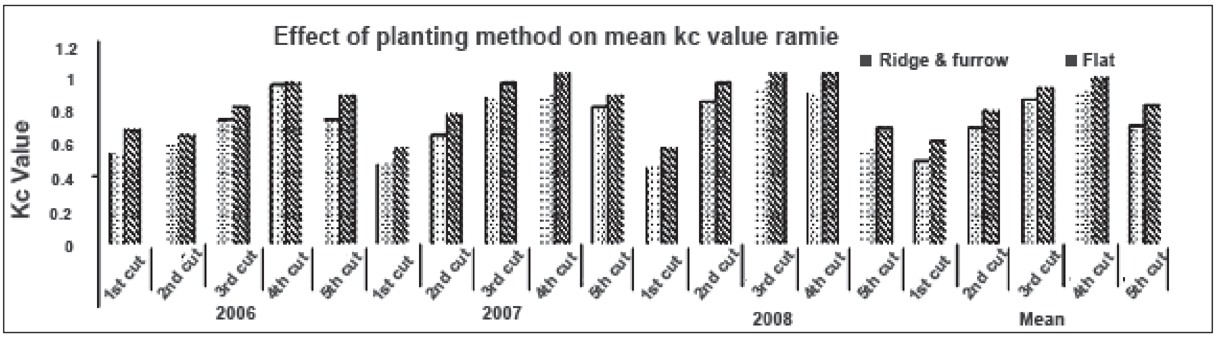



(h) Effect of planting methods on LAI of ramie (pooled)

**Fig. 2: Leaf Area Index of ramie as influenced by irrigation and planting methods**




(a) Effect of irrigation on mean $k_c$ value of ramie




(b) Effect of planting method on mean $k_c$ value of ramie

**Fig. 3: Effect of irrigation and planting methods on mean crop coefficient ($k_c$) value of ramie**

in North China (Li *et al*., 2010). Ridge planting was found to have significant influence on fibre yield of ramie in north-Bengal, India (Maity *et al*., 2007).

Thus, the primary objective of this study was to determine the effect of irrigation frequency and planting pattern on growth, fibre yield and water productivity of ramie. The results of this study may help us in recommending suitable irrigation schedule and efficient planting pattern for ramie in the Indo-Gangetic plain of West Bengal, India.

## MATERIALS AND METHODS

### *Study area*

The field experiment was conducted at Research Farm of ICAR-CRIJAF (22045'N, 88026'E and 9 m MSL) located at Barrack pore in North 24 Parganas district of West Bengal during 2006 to 2008. The experimental soil was Typic Ustocrept, sandy loam in texture with 6.1 g $kg^{-1}$ organic carbon and the values of soil available N, P and K were 246.5, 35.5 and 190 kg $ha^{-1}$, respectively. The mean bulk density of the soil (0 – 60 cm) ranged between 1.42 – 1.44 Mg $m^{-3}$. The climate of Barrack pore is tropical with mean annual maximum and minimum temperature of 41ºC and 10ºC, respectively. The monsoon lasts from early June to mid-September and the annual rainfall varies between 1250 – 1600 mm. The weather remains dry during winter (mid-Nov to mid-Feb) and humid during summer (March to May).

### *Experimental details and sampling*

The experiment was conducted in a split-plot design keeping the irrigation treatments ($I_1$: irrigation based on irrigation water/cumulative pan evaporation (IW/CPE) ratio of 0.3, $I_2$: irrigation based on IW/CPE ratio of 0.6 and $I_3$: irrigation based on IW/CPE ratio of 0.9) in the main plots and planting methods ($P_1$: ridge and furrow and $P_2$: flatbed) in sub-plots. The depth of irrigation (IW) was 40 mm. During the years of cultivation, nitrogen, phosphorus and potassium were added @ 30:6.6:12.5 kg $ha^{-1}cut^{-1}$. The ramie cultivar, Kanai (R-67-34) was grown as the experimental material. The ramie rhizomes were planted on 21st September 2005 and sprouting was observed from 15 days after planting. Gap filling was done subsequently in October month to develop uniform plant population. The stunted and uneven growth of ramie in the subsequent winter months due to low temperature were removed by cutting the canes at the base in end (stage back) of February 2006 to ensure uniform growth of the subsequent crop. This operation (stage back) was repeated in the month of February during 2007 and 2008 also. The treatments were imposed from March 2006 and observations were taken thereafter. A general irrigation was applied to all the plots after "stage back" and subsequently irrigation and fertilizers were applied to the crop as per treatments. The soil samples were collected before and 24-48 hours after irrigation from different soil depths (up to 0.90 m depth at 0.15 m interval), oven dried at 105°C for 24 hr and

**Table 1: Effect of irrigation and planting methods on fibre yield of ramie in different cuttings**

| Treatments | Fibre yield (kg ha$^{-1}$) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1$^{st}$ Cut | | | | 2$^{nd}$ Cut | | | | 3$^{rd}$ Cut | | | | 4$^{th}$ cut | | | | 5$^{th}$ cut | | | |
| | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool |
| **Irrigation** | | | | | | | | | | | | | | | | | | | | |
| $I_1$ | 189$^{c}$ | 164$^{b}$ | 179$^{b}$ | 177$^{c}$ | 234$^{b}$ | 257$^{c}$ | 228$^{b}$ | 240$^{c}$ | 526$^{*}$ | 419$^{*}$ | 347$^{*}$ | 431$^{*}$ | 467$^{*}$ | 350$^{*}$ | 399$^{*}$ | 405$^{*}$ | 133$^{c}$ | 188$^{c}$ | 131$^{b}$ | 151$^{c}$ |
| $I_2$ | 288$^{b}$ | 219$^{a}$ | 235$^{b}$ | 247$^{b}$ | 394$^{a}$ | 337$^{b}$ | 296$^{ab}$ | 342$^{b}$ | 554$^{*}$ | 429$^{*}$ | 358$^{*}$ | 447$^{*}$ | 497$^{*}$ | 351$^{*}$ | 387$^{*}$ | 412$^{*}$ | 243$^{b}$ | 245$^{b}$ | 193$^{a}$ | 227$^{b}$ |
| $I_3$ | 378$^{a}$ | 252$^{a}$ | 333$^{a}$ | 321$^{a}$ | 452$^{a}$ | 411$^{a}$ | 365$^{a}$ | 409$^{a}$ | 565$^{*}$ | 434$^{*}$ | 375$^{*}$ | 458$^{*}$ | 490$^{*}$ | 372$^{*}$ | 398$^{*}$ | 420$^{*}$ | 288$^{a}$ | 312$^{a}$ | 222$^{a}$ | 274$^{a}$ |
| **Planting method** | | | | | | | | | | | | | | | | | | | | |
| **Ridge and furrow** | 324$^{a}$ | 319$^{a}$ | 270$^{a}$ | 279$^{a}$ | 399$^{a}$ | 352$^{a}$ | 305$^{a}$ | 329$^{a}$ | 587$^{a}$ | 451$^{a}$ | 370$^{*}$ | 469$^{a}$ | 525$^{a}$ | 390$^{a}$ | 415$^{*}$ | 443$^{a}$ | 233$^{a}$ | 270$^{a}$ | 196$^{a}$ | 233$^{a}$ |
| **Flat bed** | 247$^{b}$ | 181$^{b}$ | 228$^{a}$ | 219$^{b}$ | 319$^{b}$ | 318$^{a}$ | 287$^{a}$ | 303$^{a}$ | 509$^{b}$ | 403$^{b}$ | 350$^{*}$ | 421$^{b}$ | 509$^{a}$ | 326$^{b}$ | 374$^{*}$ | 403$^{b}$ | 210$^{a}$ | 226$^{b}$ | 167$^{b}$ | 201$^{b}$ |

*$I_1$: IW/CPE =0.3, $I_1$: IW/CPE =0.6, $I_1$: IW/CPE =0.9; I: 2006, II: 2007, III: 2008; *, treatment effect non-significant; treatment means with different letters significantly different*

**Table 2: Effect of irrigation and planting methods on total annual fibre yield of ramie**

| Treatments | Annual fibre yield (kg ha$^{-1}$) | | | |
|---|---|---|---|---|
| | 2006 | 2007 | 2008 | Pool |
| **Irrigation** | | | | |
| $I_1$ | 1549$^{b}$ | 1378$^{b}$ | 1283$^{b}$ | 1403$^{b}$ |
| $I_2$ | 1976$^{a}$ | 1581$^{ab}$ | 1469$^{ab}$ | 1675$^{a}$ |
| $I_3$ | 2173$^{a}$ | 1782$^{a}$ | 1692$^{a}$ | 1882$^{a}$ |
| **Planting method** | | | | |
| **Ridge and furrow** | 2068$^{a}$ | 1705$^{a}$ | 1538$^{a}$ | 1770$^{a}$ |
| **Flat bed** | 1794$^{b}$ | 1455$^{b}$ | 1425$^{b}$ | 1558$^{b}$ |

**Table 3: Effect of irrigation and planting methods on consumptive water use of ramie**

| Treatments | Consumptive water use of ramie (mm) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1$^{st}$ Cut | | | | 2$^{nd}$ Cut | | | | 3$^{rd}$ Cut | | | | 4$^{th}$ cut | | | | 5$^{th}$ cut | | | | Annual | | | |
| | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool |
| **Irrigation** | | | | | | | | | | | | | | | | | | | | | | | | |
| $I_1$ | 111$^{c}$ | 95$^{c}$ | 96$^{c}$ | 101$^{c}$ | 165$^{c}$ | 157$^{b}$ | 206$^{b}$ | 176$^{c}$ | 163$^{*}$ | 169$^{*}$ | 195$^{*}$ | 176$^{*}$ | 163$^{*}$ | 149$^{*}$ | 160$^{*}$ | 157$^{*}$ | 97$^{b}$ | 99$^{b}$ | 51$^{c}$ | 82$^{c}$ | 699$^{c}$ | 669$^{c}$ | 708$^{c}$ | 692$^{c}$ |
| $I_2$ | 133$^{b}$ | 124$^{b}$ | 121$^{b}$ | 126$^{b}$ | 193$^{b}$ | 174$^{ab}$ | 226$^{ab}$ | 198$^{b}$ | 167$^{*}$ | 173$^{*}$ | 196$^{*}$ | 179$^{*}$ | 167$^{*}$ | 153$^{*}$ | 162$^{*}$ | 160$^{*}$ | 123$^{ab}$ | 110$^{b}$ | 86$^{b}$ | 106$^{b}$ | 783$^{b}$ | 734$^{b}$ | 791$^{b}$ | 769$^{b}$ |
| $I_3$ | 158$^{a}$ | 181$^{a}$ | 154$^{a}$ | 164$^{a}$ | 227$^{a}$ | 194$^{a}$ | 233$^{a}$ | 218$^{a}$ | 168$^{*}$ | 177$^{*}$ | 195$^{*}$ | 180$^{*}$ | 164$^{*}$ | 153$^{*}$ | 179$^{*}$ | 166$^{*}$ | 125$^{a}$ | 128$^{a}$ | 119$^{a}$ | 124$^{a}$ | 842$^{a}$ | 833$^{a}$ | 880$^{a}$ | 852$^{a}$ |
| **Planting method** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Ridge and furrow** | 118$^{b}$ | 120$^{b}$ | 109$^{b}$ | 109$^{b}$ | 184$^{b}$ | 156$^{b}$ | 209$^{b}$ | 183$^{b}$ | 166$^{b}$ | 191$^{*}$ | 162$^{*}$ | 191$^{*}$ | 162$^{*}$ | 142$^{b}$ | 159$^{b}$ | 154$^{b}$ | 104$^{b}$ | 107$^{b}$ | 76$^{b}$ | 96$^{b}$ | 734$^{b}$ | 716$^{b}$ | 744$^{b}$ | 731$^{b}$ |
| **Flat bed** | 150$^{a}$ | 146$^{a}$ | 138$^{a}$ | 138$^{a}$ | 206$^{a}$ | 187$^{a}$ | 235$^{a}$ | 209$^{a}$ | 180$^{a}$ | 199$^{*}$ | 166$^{*}$ | 200$^{*}$ | 166$^{*}$ | 161$^{a}$ | 177$^{a}$ | 168$^{a}$ | 126$^{a}$ | 118$^{a}$ | 94$^{a}$ | 112$^{a}$ | 828$^{a}$ | 811$^{a}$ | 844$^{a}$ | 828$^{a}$ |

*$I_1$: IW/CPE =0.3, $I_1$: IW/CPE =0.6, $I_1$: IW/CPE =0.9; I: 2006, II: 2007, III: 2008; treatment means with different letters significantly different; *: treatment effect non-significant*

**Table 4: Effect of irrigation and planting methods on water use efficiency of ramie**

| Treatments | Water use efficiency of ramie (kg ha-mm$^{-1}$) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1$^{st}$ Cut | | | | 2$^{nd}$ Cut | | | | 3$^{rd}$ Cut | | | | 4$^{th}$ cut | | | | 5$^{th}$ cut | | | | Annual | | | |
| | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool | I | II | III | Pool |
| **Irrigation** | | | | | | | | | | | | | | | | | | | | | | | | |
| $I_1$ | 1.70$^{c}$ | 1.73$^{ab}$ | 1.86$^{b}$ | 1.75$^{b}$ | 1.42$^{b}$ | 1.64$^{c}$ | 1.11$^{c}$ | 1.36$^{c}$ | 3.23$^{*}$ | 2.48$^{*}$ | 1.78$^{*}$ | 2.45$^{*}$ | 2.87$^{*}$ | 2.35$^{*}$ | 2.49$^{*}$ | 2.58$^{*}$ | 1.37$^{c}$ | 1.90$^{c}$ | 2.57$^{a}$ | 1.84$^{b}$ | 2.22$^{b}$ | 2.06$^{b}$ | 1.81$^{b}$ | 2.03$^{b}$ |
| $I_2$ | 2.17$^{b}$ | 1.77$^{a}$ | 1.94$^{b}$ | 1.96$^{a}$ | 2.04$^{a}$ | 1.94$^{b}$ | 1.31$^{b}$ | 1.73$^{b}$ | 3.32$^{*}$ | 2.48$^{*}$ | 1.83$^{*}$ | 2.50$^{*}$ | 2.98$^{*}$ | 2.29$^{*}$ | 2.39$^{*}$ | 2.58$^{*}$ | 1.98$^{b}$ | 2.23$^{b}$ | 2.24$^{b}$ | 2.14$^{a}$ | 2.52$^{a}$ | 2.15$^{a}$ | 1.86$^{a}$ | 2.18$^{a}$ |
| $I_3$ | 2.39$^{a}$ | 1.39$^{b}$ | 2.16$^{a}$ | 1.96$^{a}$ | 1.99$^{a}$ | 2.12$^{a}$ | 1.57$^{a}$ | 1.88$^{a}$ | 3.36$^{*}$ | 2.45$^{*}$ | 1.92$^{*}$ | 2.54$^{*}$ | 2.99$^{*}$ | 2.43$^{*}$ | 2.22$^{*}$ | 2.53$^{*}$ | 2.30$^{a}$ | 2.44$^{a}$ | 1.87$^{c}$ | 2.21$^{a}$ | 2.58$^{a}$ | 2.14$^{a}$ | 1.92$^{a}$ | 2.21$^{a}$ |
| **Planting method** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Ridge and furrow** | 2.75a | 2.66$^{a}$ | 2.48$^{a}$ | 2.56$^{a}$ | 2.17$^{a}$ | 2.26$^{a}$ | 1.46$^{a}$ | 1.80$^{a}$ | 3.54$^{a}$ | 2.36$^{a}$ | 1.94$^{*}$ | 2.57$^{a}$ | 3.24$^{*}$ | 2.75$^{a}$ | 2.61$^{a}$ | 2.88$^{a}$ | 2.24$^{a}$ | 2.52$^{a}$ | 2.58$^{a}$ | 2.43$^{a}$ | 2.82$^{a}$ | 2.49$^{a}$ | 2.09$^{a}$ | 2.40$^{a}$ |
| **Flat bed** | 1.65$^{b}$ | 1.24$^{b}$ | 1.65$^{b}$ | 1.59$^{b}$ | 1.55$^{b}$ | 1.70$^{b}$ | 1.22$^{b}$ | 1.45$^{b}$ | 2.83$^{b}$ | 2.03$^{b}$ | 1.75$^{*}$ | 2.18$^{b}$ | 3.07$^{*}$ | 2.02$^{b}$ | 2.11$^{b}$ | 2.40$^{b}$ | 1.67$^{b}$ | 1.92$^{b}$ | 1.78$^{b}$ | 1.79$^{b}$ | 2.17$^{b}$ | 1.79$^{b}$ | 1.67$^{b}$ | 1.87$^{b}$ |

the moisture content was determined thermo-gravimetrically. During the study period, five cuttings were made each year at an interval of 45-55 days depending upon the physiological maturity of the crop which was ascertained when 2/3$^{rd}$ length of the canes from the base became brown in colour. The fibre was extracted mechanically using a 5 HP fibre extraction machine (Raspador Decorticator), washed in clean water, sun dried and fibre weight was expressed in t ha$^{-1}$. The crop received 1389.6, 1751.2 and 1333.8 mm rainfall during 2006, 2007 and 2008, respectively against the normal annual rainfall of 1579 mm. The distribution of rainfall and evaporation during the entire crop growth period under study (2006-2008) had been presented graphically in fig. 1.

### *Methods of analysis*

The consumptive water use (CU) by the crop was calculated as per Dastane (1972) and effective rainfall was calculated as per Dastane (1974). The leaf area index (LAI) was measured with LAI-2000 Plant Canopy Imager (LI-COR). The measurements were taken from five plants in each plot on clear sunny days between 10.00 and 11.30 hours IST. The data on growth parameters, fibre yield and water use by ramie were analyzed using ANOVA as per Gomez and Gomez (1984) and the significant difference among the treatment means were analyzed by Duncan's Multiple Range Test using SAS v 9.2 (SAS Institute, Cary, NC).

## RESULTS AND DISCUSSION

### *Leaf area index*

The perusal of experimental data revealed that the leaf area index of ramie was significantly influenced by irrigation and planting methods during its growth period in the individual years of experimentation and also when the data was pooled (Fig. 2). In this experiment IW/CPE method had been chosen as the method for irrigation scheduling to ramie. In IW/CPE approach, the irrigation is scheduled on the basis of a specific IW/CPE ratio and the users need to calculate the CPE value based on the daily pan evaporation data collected from the nearby meteorological observatory as the depth of irrigation (IW) is determined experimentally for the given soil type and crop chosen. The method is simple compared to other methods of irrigation scheduling, requiring only pan evaporation data and is relatively easy to be transferred to the end users, *i.e*. farmers. The LAI of ramie increased progressively and reached maximum value (4.90 – 5.43) during 3$^{rd}$ and 4$^{th}$ cuttings and declined thereafter in all the irrigation treatments. The increase in irrigation frequency significantly increased the LAI of the crop up to 0.6 IW/CPE ratio ($I_2$) only during 1$^{st}$, 2$^{nd}$ and 5$^{th}$ cuttings in all the years of experimentations. Similar trend was observed when the data was pooled (Fig. 2). The higher LAI of ramie recorded in $I_2$ and $I_3$ irrigation treatment plots compared to $I_1$ (0.3 IW/CPE ratio) treatment in 1$^{st}$, 2$^{nd}$ and 5$^{th}$ cuttings may be attributed to the fact that ramie crop received 1-2 additional irrigations in $I_2$ and $I_3$ treatments compared to $I_1$ treatment which had led to better growth and leaf area development of ramie in the former treatments. During 3$^{rd}$ and 4$^{th}$ cuttings, the variation in LAI was not significantly influenced by irrigation in all the years of experimentation possibly due to excess rainfall during the period which might have nullified the effect of irrigation. The experimental results corroborate the findings of Mitra *et al*. (2014) who also reported the non-significant effect of irrigation on LAI of ramie during this period. Planting of ramie in ridge and furrow system had significantly increased the LAI of the crop over flatbed planting during the entire growth period in the individual years of experimentation and also when the data was pooled (Fig. 2). This was possibly because of better in-situ conservation of moisture in furrows during the dry period and also due to better drainage of excess water and proper aeration in the root zone of ramie crop compared to flat-bed planting during the wet period. Similar impact of ridge furrow planting on growth of faba bean was reported by El-Sadek and Salem (2015).

### *Fibre yield*

The experimental data revealed that fibre yield of ramie was significantly influenced by irrigation and planting methods. The ramie crop, irrespective of the irrigation and planting treatments, recorded maximum fibre yield (5.09-5.54 q ha$^{-1}$) during the 3$^{rd}$ cutting during all the three years of experimentation. It was observed that during the first cutting, fibre yield of the crop increased significantly up to the highest irrigation frequency, *i.e*. 0.9 IW/CPE ratio ($I_3$), except in second year when the increase was significant up to 0.6 IW/CPE ratio ($I_2$) only. During the 2nd and 5th cuttings, the yield increase was significant mostly up to $I_2$ irrigation level only (table 1). No significant variation in yield of ramie due to irrigation was observed during 3$^{rd}$ and 5th cuttings in all the years possibly because the effect of irrigation was masked by the excess rainfall during this period. The average annual fibre yield of the crop increased significantly upto $I_2$ irrigation treatment only, during all the years of experimentation and also when the data was pooled (Table 2). The crop receiving irrigation based on 0.6 IW/CPE ratio ($I_2$) possibly received favorable soil moisture condition, developed better LAI which had finally led to increased fibre yield of the crop compared to other irrigation treatments. In other experimental studies also, similar increase in irrigation frequency had been found to increase economic yield in wheat (Mitra *et al.*, 2006), jute (Mitra *et al.*, 2011) and frenchbean (Patel *et al.*, 2010).

The ridge and furrow planting system recorded significantly higher fibre yield of the crop over flatbed planting during the entire growth period in the individual years of experimentation and also when the data was pooled (Table 1). The pooled data on yield revealed that ridge planting, on an average, recorded 14 per cent higher fibre yield of ramie over flat planting. Similar trend was observed in annual fibre yield also (Table 2). This was possibly because of better in-situ conservation of moisture in furrows leading to increased water availability in root zone of the crop during the dry period and also due to better drainage of excess water and proper aeration in the root zone of ramie crop in ridge planting particularly during the wet period. The results are in conformity with the earlier findings of Zhang *et al.* (2007) who also reported that sowing of winter wheat on furrow irrigated raise bed recorded 5.2 per cent higher grain yield of the crop compared to flat planting method.

***Water use***

The consumptive water use by ramie increased significantly with increase in irrigation frequency and maximum water use by the crop was recorded in $I_3$ irrigation treatment during the pre-monsoon, *i.e*. 1$^{st}$ and 2$^{nd}$ cuttings as well as in the post monsoon period, i.e. 5$^{th}$ cutting, during all the three years and also when the data were pooled (Table 3). Alike the fibre yield data, no significant variation was observed in water use by ramie under different irrigation treatments during 3$^{rd}$ and 4$^{th}$ cuttings, possibly due to excess rainfall during the period. Similar trend was recorded in the annual consumptive water use by the crop (Table 3). It was also observed that ramie crop receiving $I_3$ irrigation treatment consumed 7.5 to 13.6 and 20.0 to 24.5 per cent more moisture compared to $I_2$ and $I_1$ irrigation treatments, respectively. This might be due to the fact the ramie crop under $I_3$ irrigation treatment received one to two irrigations more compared to $I_2$ and $I_1$ irrigation treatments. Increased water consumption with higher irrigation frequency was also observed in winter wheat in China (Bian *et al*., 2016). Flatbed planting recorded significantly higher consumptive water use of ramie compared to ridge and furrow planting system throughout its growth period except during the 3$^{rd}$ cutting. The ramie plants grown in flat beds consumed 13 – 14 per cent more water compared to those under ridge and furrow planting system (Table 3). The lesser water consumption by ramie crop grown in ridge and furrow system compared to conventional flat planting system can be attributed to reduced irrigation water requirement as well as controlled evaporation from top soil resulting from land surface modification. Similar results were observed by Zhang *et al*. (2007) in winter wheat.

The water use efficiency (WUE) of ramie in each individual cutting when pooled, revealed that the WUE with $I_2$ irrigation treatment was statistically at par with that of $I_3$ treatment while both the irrigation treatments recorded significantly higher WUE over $I_1$ treatment during 1$^{st}$, 2$^{nd}$ and 5$^{th}$ cuttings, respectively (Table 4). The mean WUE of ramie in a year (averaged over 5 cuttings) also showed similar trend in each experimental year and also when the data was pooled. On an average, $I_2$ and $I_3$ irrigation treatments recorded 5.4 – 16 per cent higher WUE over $I_1$ treatment possibly due to higher fibre yield in $I_2$ and $I_3$ treatments compared to $I_1$. The results are in conformity with the findings of *Mitra et al*. (2014). Ramie crop planted on ridges recorded significantly higher WUE compared to flatbed planting throughout the growth period in all the years of experimentation and also when the data were pooled (Table 4) and the average annual increase was found to be 25.1 – 41 per cent. The increased WUE of ramie under ridge and furrow system may be attributed to the favourable soil moisture conditions experienced by the ramie crop raised in ridge and furrow system compared to flatbed planting. Increased WUE with ridge planting was also observed in maize-wheat cropping system (Naresh *et al.,* 2012).

The mean crop coefficient ($k_c$) value of ramie increased progressively with increasing irrigation frequency during both pre (1st and 2nd cuttings) and post – monsoon (5th cutting) periods while during the monsoon period coinciding with 3rd and 4th cuttings of the crop, the $k_c$ value of ramie did not show much difference with varying irrigation levels (Fig 3). The $k_c$ value of ramie ranged between 0.37 to 0.72, 0.52 to 0.91 and 0.38 to 0.96 during 1$^{st}$, 2$^{nd}$ and 5$^{th}$ cuttings of the crop, respectively, with maximum value being recorded with highest irrigation frequency, *i.e*. in $I_3$ irrigation treatment. The higher irrigation frequency in $I_3$ irrigation treatment resulted into more availability of water both in the top soil as well root zone of the crop compared to $I_1$ and $I_2$ treatments which might have led to increased evapotranspiration by ramie and finally higher kc value of the crop during 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ cuttings, respectively. The ramie crop planted on flat-beds, on an average, recorded 14.5 - 24.5 and 17.1per cent higher $k_c$ value over ridge planted crop during pre-monsoon (1$^{st}$ and 2$^{nd}$ cuttings) and post monsoon (5$^{th}$ cutting) periods, respectively (Fig. 3). This was possibly due to more wetting of soil as well as higher evaporation from the soil surface under flat planting system compared to that in ridge and furrow planting system.

It was observed in the present study that scheduling irrigation to ramie, based on IW/CPE ratio of 0.6 recorded significantly higher LAI and fibre yield of ramie over other irrigation treatments and also lead to 10.2 – 31.2 per cent savings in irrigation water and is thus, recommended for the crop in Indo-Gangetic plains of West Bengal. Ramie crop can be planted in ridge and furrow system in this region as this planting method, on an average, recorded 14 per cent higher fibre yield and 25-41 per cent higher water use efficiency of the crop.

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