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## EFFECT OF INTENSITY AND TIMING OF DEFOLIATION ON SEED YIELD AND YIELD COMPONENTS IN OILSEED GOURD AND ITS IMPLICATION IN INSECT PESTS' SUSTAINABLE CONTROL

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### ABSTRACT

Dual-purpose cropping for both leaf and seed production can be highly profitable if leaf removal by pests or farmers does not cause significant loss of seed yield. The objective of this study was to access the effect of defoliation intensity and timing on 7 yield and yield components for the cucurbit *Lagenaria siceraria*. The study was done in 2013 and 2014. Four defoliation intensities (0, 25, 50 and 75%) were applied to the crop at three phenological stages (tendrils, flowering and fruit setting stage) in a split plot design. For all the yield traits examined, no significant difference was found between the control and 25% leaf defoliation, whatever the plant-phenological stage. However, intense defoliation negatively affected seed production (from  $1.99 \pm 0.98 \text{ t ha}^{-1}$  with the control to  $1.41 \pm 1.07 \text{ t ha}^{-1}$  with 75% defoliation), irrespective of the growth stage of the plant. Seed yield decreased when defoliation was applied at advanced phenological stage, varying from a mean of  $1.99 \pm 0.98 \text{ t ha}^{-1}$  (tendrils) to  $1.55 \pm 0.34 \text{ t ha}^{-1}$  (fruit setting). The results suggested that the intensity of defoliation when harvesting the leaves or to trigger the treatment of bottle gourd against leaves damaging pests is about 25%, whatever the timing.

*Key Words:* Defoliation, *Lagenaria siceraria*, phenological stage, yield

### RÉSUMÉ

Une culture à double usage pour la production de feuilles et de semences peut être très rentable si l'élimination des feuilles par des organismes nuisibles ou des agriculteurs ne provoque pas de perte significative de rendement en semences. L'objectif de cette étude était de déterminer l'effet de l'intensité de la défoliation et de la synchronisation sur le rendement et les composantes du rendement pour la cucurbitacée *Lagenaria siceraria*. L'étude a été réalisée en 2013 et 2014. Quatre intensités de défoliation (0, 25, 50 et 75%) ont été appliquées à la culture à trois stades phénologiques (stade vrille, floraison et nouaison) en parcelles divisées. Pour toutes les caractéristiques de rendement examinées, aucune différence significative n'a été observée entre la défoliation témoin et la défoliation foliaire à 25%, quel

que soit le stade phénologique de la plante. Cependant, une défoliation intense a eu un effet négatif sur la production de semences (de  $1,99 \pm 0,98 \text{ t ha}^{-1}$  avec le témoin à  $1,41 \pm 1,07 \text{ t ha}^{-1}$  avec une défoliation à 75%), quel que soit le stade de croissance de la plante. Le rendement en semences diminuait lorsque la défoliation était appliquée à un stade phénologique avancé, variant entre une moyenne de  $1,99 \pm 0,98 \text{ t ha}^{-1}$  (vrille) à  $1,55 \pm 0,34 \text{ t ha}^{-1}$  (nouaison). Les résultats suggèrent que l'intensité de la défoliation lors de la récolte des feuilles ou pour déclencher le traitement de la gourde contre les ravageurs nuisibles aux feuilles est d'environ 25%, quel que soit le moment.

*Mots Clés:* Défoliation, *Lagenaria siceraria*, stade phénologique, rendement

## INTRODUCTION

Gourd [*Lagenaria siceraria* (Molina) Standley] widely grown in diverse agro-ecosystems stands as a good plant model in the context of climate variability. This annual monoecious species belonging to Cucurbitaceae family is a vigorous trailer or climber and is well adapted to various crop husbandries. It is widely cultivated in the tropics and subtropics (Harika *et al.*, 2012), due to its extensive range of uses. Landraces of gourd have a tremendous diversity, especially in fruit shape and size. Edible varieties produce seeds rich in lipids and proteins (Loukou *et al.*, 2011, 2013). However, susceptibility of this crop to insects' herbivory has been demonstrated as one of its main yield reducing factors (Adja *et al.*, 2014; Anzara *et al.*, 2015). Investigations on insect pests' sustainable management strategy are required to effectively use *L. siceraria* as model plant in the development of climate-smart cropping systems. Determining the threshold beyond which defoliation can cause a significant decrease in yield is a prerequisite to calculate the appropriate concentration and application frequency of pesticides. Such data are also of practical interest in the context of dual-purpose cropping for both leaf and seed production.

This study is part of a research program aimed at optimising a management technique to increase the yield of *L. siceraria*. Investigations were designed to assess the effect of defoliation intensity applied to different plant phenological stages on the growth and yield of *L. siceraria*.

## MATERIALS AND METHODS

**Study site.** The study was conducted at the experimental station of the Nangui Abrogoua University in Abidjan (Côte d'Ivoire) during two consecutive years (April to July 2013 and 2014). The study site is located between  $5^{\circ}17'N$  and  $5^{\circ}31'N$  and  $3^{\circ}45'W$  and  $4^{\circ}22'W$ . The climate is a wet subequatorial, with mean annual rainfall of 1350 mm, and mean annual temperature of about  $25^{\circ}C$  (Kouonon *et al.*, 2009). The soil is ferrallitic, characterised by the forest land, and has a sand-clay texture and cluster structure (Yao-Kouamé and Kane, 2008).

**Plant material and experimental design.** The round-fruited cultivar bearing seeds characterised by the presence of a cap on the distal side was selected from *L. Siceraria* germplasm collection of Nangui Abrogoua University (Abidjan, Côte d'Ivoire), to conduct this study. This cultivar was used because of its high yielding potential and its large distribution range in Western and Central Africa.

The experimental design was a split plot measuring 68 m x 34 m and was established at the experimental station of the Nangui Abrogoua University in Abidjan (Côte d'Ivoire). The main plot treatment was plant phenological stage, and included tendrill flowering and fruit setting stages. The subplot treatment was defoliation intensity in which 0, 25, 50 and 75% of leaves on a plant were cut. Each treatment combination corresponded

to a sub-plot of 72 m<sup>2</sup> (12 m x 6 m). Consecutive sub-plots were separated by a 4 m-wide bare land strips and regularly weeded. In each sub-plot 15 plants were grown on 3 lines of 5 holes and with 3 m between holes and lines. The experiment was carried out for two years during 2013 and 2014.

**Crop traits and data analysis.** Seven seed yield and yield components selected from the descriptors of cucurbit (Staub, 1988; Koffi, 2009) were examined in this study. They included plant length (PL), number of branches (NB), number of fruits per plant (NF), fruit weight (FW), number of seeds per fruit (NS), 100-seed weight (100-SW) and seed yield per plant (SY). PL and NB were recorded on 15 plants sampled per replication; PL was measured with a tape meter. NF and FW were recorded on each of the 15 plants in a plot. Fruit weight was determined using a commercial balance. At maturity, plants bearing at least 5 fruits in each plot were sampled to access NS and 100-SW; 100-SW was measured using a precision balance (OHAUS; Precision Electronic Balance, AX4202M). SY was then deduced from 100-SW, NS and NF.

Mean values and standard deviations were calculated for each trait. For each trait, these values were compared among years using Student t-test, after checking variances homogeneity by Fisher-Snedecor F test. Combined multivariate analysis of variance (MANOVA) appropriate for two factors (phenological stage and defoliation intensity) and several independent variables was performed to check treatment effects, as well as their interactions. This allowed the identification of significant factors based on a vector of dependent variables. The General Linear Models (GLM) procedure of the SAS v.9.1 (SAS, 2004) was used to identify traits contributing to differences when MANOVA revealed significant factor effect. Mean separation in a row was carried out by Least Significance Difference (LSD) test at 5% level.

## RESULTS

Figure 1 shows the results of among year comparisons of yield components. Statistical analyses revealed significant differences for 16 out of the 24 Student t-tests carried out. Where significant differences were noted, values obtained in 2014 were higher than those of 2013 for all traits, except plant length. MANOVA showed significant effects of phenological stage (F=12.35; P<0.001), defoliation intensity (F=8.44; P<0.001), and their interactions (F=3.57; P<0.01). The trends of results related to the effects of the factors tested did not change through the two years of study. Consequently, data for the two factors were pooled over years and only means are presented. GLM carried out to examine the influence of phenological stage indicated significant effect for all the traits analysed (Table 1). Significantly decreasing values of traits analysed were observed for advanced phenological stages, resulting in low seed yield (24% lower than control). The results of ANOVA 1 examining the effect of defoliation intensity are presented in Table 2. This table shows that significant reduction of yield components was noted when 25% of leaves were cut. Seed yield decrease when defoliation intensity reached 50% was significant (0.37 t ha<sup>-1</sup> i.e. about 20%).

Statistical analysis of the interaction between the defoliation intensity and phenological stage highlighted a significant variation for seed yield and all the yield components tested (Table 3). The highest values of seed yield were obtained with the low defoliation intensity (0-25%) regardless of the phenological stage. There was no significant difference between the control and 25% plant defoliation, whatever the plant growing stage. This trend was similar for all yield components examined except the number of fruits per plant. Statistical results also showed that its comparison with plant growth stages, seed yield decreased when defoliation was applied at advanced phenological stage

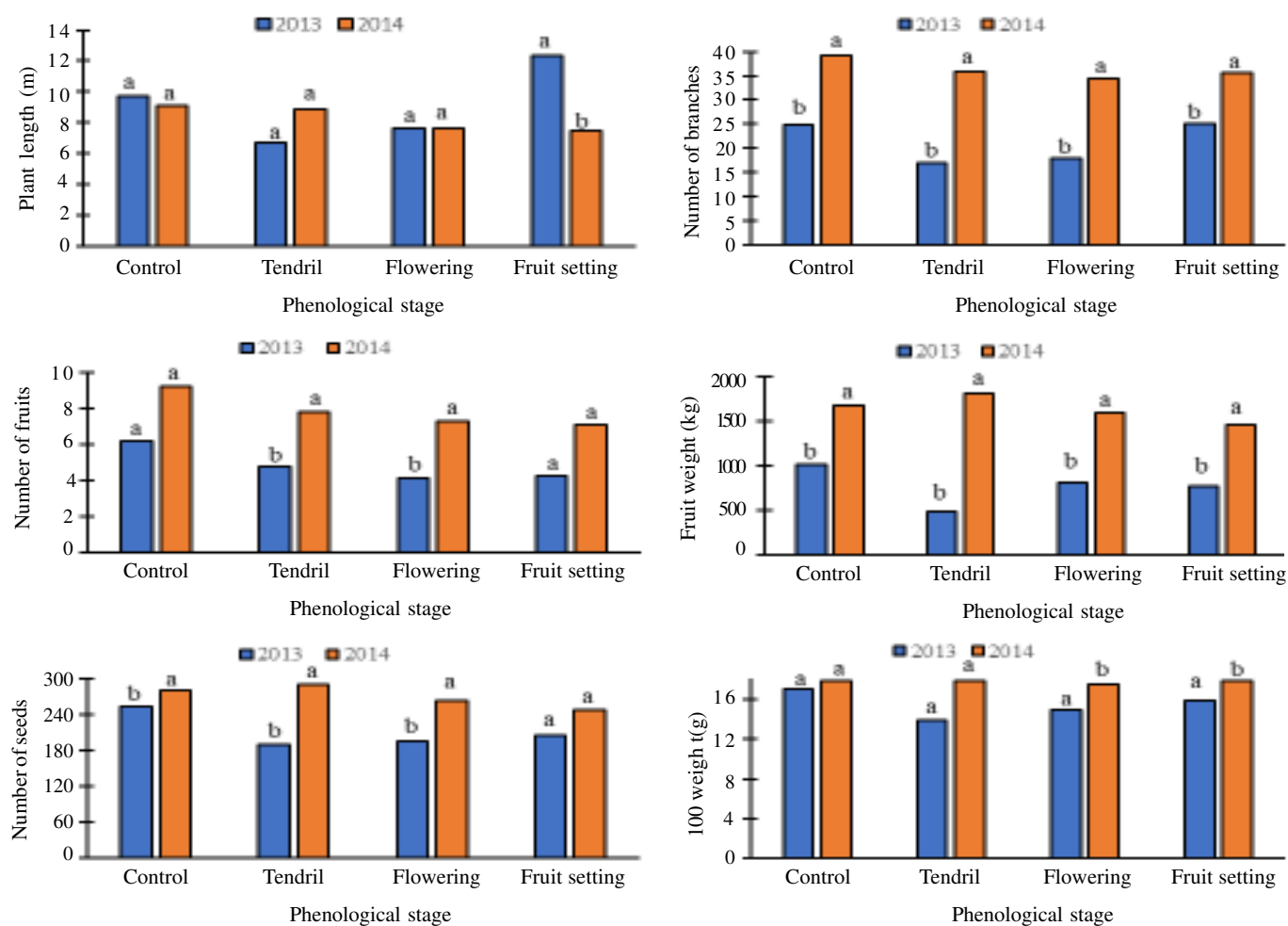


Figure 1. Between years variation of yield components in the gourd with respect to plant phenological stage. Bars (means) with the same letter at a phenological stage were not significantly different ( $P > 0.05$ ).

TABLE 1. Effect of defoliation timing on the bottle gourd yield and its components at Nangui Abrogoua University in Côte d'Ivoire (2013 - 2014)

Stages	PL (m)	NB	NF	NS	FW (g)	100-SW (g)	SY (t ha <sup>-1</sup> )
Control	9.30±2.09 <sup>a</sup>	33.71±10.20 <sup>a</sup>	8.11±3.05 <sup>a</sup>	272.40±64.55 <sup>a</sup>	1451.05±481.44 <sup>ab</sup>	17.55±2.91 <sup>a</sup>	1.99±0.98 <sup>a</sup>
Tendril	6.97±2.64 <sup>b</sup>	26.59±12.63 <sup>b</sup>	5.80±3.46 <sup>b</sup>	270.69±94.43 <sup>a</sup>	1540.48±624.60 <sup>a</sup>	16.53±4.19 <sup>b</sup>	1.95±1.43 <sup>a</sup>
Flowering	7.33±0.68 <sup>b</sup>	25.77±10.96 <sup>b</sup>	5.55±2.16 <sup>b</sup>	243.07±86.25 <sup>b</sup>	1393.38±548.97 <sup>b</sup>	16.81±3.40 <sup>ab</sup>	1.59±1.23 <sup>b</sup>
Fruit setting	9.23±2.68 <sup>a</sup>	29.89±8.60 <sup>ab</sup>	5.29±2.32 <sup>b</sup>	238.27±85.52 <sup>b</sup>	1251.12±502.32 <sup>c</sup>	17.11±5.43 <sup>ab</sup>	1.51±1.07 <sup>b</sup>
F	44.57	4.59	2.10	16.98	4.45	6.74	14.09
P	<0.001	0.003	0.010	<0.001	0.004	<0.001	<0.001

Mean separation in a row by Least Significance Difference (LSD) test at 5% level. Means followed by the same letter are not significantly different at the 5% level. PL = plant length; NB = number of branching; NF = number of fruits per plant; FW = fruit weight; NS = number of seeds per fruit; 100-SW = 100 seeds weight; SY = seed yield

TABLE 2. Effect of defoliation intensity on the gourd yield and its components at Nangui Abrogoua University in Côte d'Ivoire (2013 - 2014)

Defoliation intensity (%)	PL (m)	NB	NF	NS	FW (g)	100-SW (g)	SY (t ha <sup>-1</sup> )
0 (Control)	9.36±2.21 <sup>a</sup>	32.14±12.38 <sup>a</sup>	8.12±3.32 <sup>a</sup>	272.63±64.60 <sup>a</sup>	1449.72±481.34 <sup>a</sup>	17.55±2.90 <sup>a</sup>	1.99±0.98 <sup>a</sup>
25	8.61±2.63 <sup>ab</sup>	31.08±12.43 <sup>a</sup>	6.75±2.96 <sup>b</sup>	273.96±86.21 <sup>a</sup>	1398.66±570.13 <sup>b</sup>	17.02±3.31 <sup>a</sup>	1.95±1.32 <sup>a</sup>
50	8.32±2.12 <sup>b</sup>	28.18±9.86 <sup>ab</sup>	5.51±2.23 <sup>c</sup>	238.83±86.69 <sup>b</sup>	1399.83±581.63 <sup>b</sup>	17.33±5.76 <sup>a</sup>	1.62±1.24 <sup>b</sup>
75	7.18±2.02 <sup>c</sup>	24.90±8.56 <sup>b</sup>	4.54±2.44 <sup>c</sup>	234.61±91.12 <sup>b</sup>	1377.97±560.85 <sup>b</sup>	16.08±3.80 <sup>b</sup>	1.41±1.13 <sup>b</sup>
F	23.89	8.56	16.07	10.63	3.65	3.34	13.13
P	<0.001	<0.001	<0.001	<0.001	0.012	0.005	<0.001

Mean separation in a row by Least Significance Difference (LSD) test at 5% level. Means followed by the same letter are not significantly different at the 5% level. PL = plant length; NB = number of branching; NF = number of fruits per plant; FW = fruit weight; NS = number of seeds per fruit; 100-SW = 100 seeds weight; SY = seed yield

Defoliation effect on production in gourd

TABLE 3. Combined effect of defoliation intensity and timing on gourd yield and its components at Nangui Abrogoua University in Côte d'Ivoire (2013 -2014) 94

Phenological stage	Defoliation intensity (%)	<sup>1</sup> PL (m)	NB	NF	FW (g)	NS	100-SW (g)	SY (t ha <sup>-1</sup> )
Tendrils	0	9.31 ± 1.68 <sup>ab</sup>	40.33 ± 6.86 <sup>ab</sup>	9.04 ± 2.31 <sup>a</sup>	1588.93 ± 500.14 <sup>a</sup>	290.63 ± 64.28 <sup>a</sup>	18.26 ± 2.56 <sup>a</sup>	2.43 ± 1.04 <sup>a</sup>
	25	9.59 ± 2.05 <sup>a</sup>	41.66 ± 9.40 <sup>ab</sup>	7.20 ± 4.12 <sup>bc</sup>	1528.83 ± 563.65 <sup>ab</sup>	289.32 ± 82.37 <sup>ab</sup>	17.75 ± 3.45 <sup>abc</sup>	2.22 ± 1.44 <sup>a</sup>
	50	8.49 ± 1.72 <sup>b</sup>	32.13 ± 6.09 <sup>de</sup>	5.65 ± 2.33 <sup>defgh</sup>	1519.19 ± 701.80 <sup>ab</sup>	257.53 ± 99.21 <sup>cde</sup>	16.43 ± 4.66 <sup>fg</sup>	1.90 ± 1.51 <sup>b</sup>
	75	8.19 ± 1.61 <sup>b</sup>	29.66 ± 6.90 <sup>ef</sup>	4.60 ± 3.39 <sup>gh</sup>	1581.98 ± 603.51 <sup>ab</sup>	262.43 ± 99.57 <sup>cd</sup>	15.22 ± 4.15 <sup>h</sup>	1.65 ± 1.25 <sup>bcd</sup>
Flowering	0	8.26 ± 1.20 <sup>b</sup>	37.86 ± 7.31 <sup>abc</sup>	7.20 ± 4.02 <sup>bc</sup>	1383.38 ± 481.12 <sup>bc</sup>	262.68 ± 69.61 <sup>cd</sup>	16.47 ± 2.71 <sup>eg</sup>	1.71 ± 0.87 <sup>bc</sup>
	25	7.65 ± 0.97 <sup>bc</sup>	35.93 ± 8.51 <sup>bcd</sup>	6.44 ± 2.16 <sup>ce</sup>	1441.74 ± 547.61 <sup>b</sup>	263.69 ± 94.16 <sup>cd</sup>	16.71 ± 3.37 <sup>cdeg</sup>	1.86 ± 1.41 <sup>b</sup>
	50	7.09 ± 0.77 <sup>bc</sup>	32.13 ± 4.70 <sup>de</sup>	5.92 ± 2.34 <sup>cdefg</sup>	1387.85 ± 536.97 <sup>bc</sup>	222.42 ± 70.33 <sup>fg</sup>	17.61 ± 3.73 <sup>abcd</sup>	1.36 ± 0.90 <sup>de</sup>
	75	7.39 ± 0.81 <sup>bc</sup>	31.60 ± 5.99 <sup>def</sup>	4.76 ± 1.64 <sup>fgh</sup>	1348.38 ± 563.58 <sup>bcd</sup>	242.68 ± 88.07 <sup>def</sup>	16.07 ± 2.87 <sup>gh</sup>	1.53 ± 1.26 <sup>cd</sup>
Fruit setting	0	8.35 ± 1.23 <sup>b</sup>	41.93 ± 8.40 <sup>a</sup>	8.12 ± 3.29 <sup>ab</sup>	1361.06 ± 427.70 <sup>bcd</sup>	262.46 ± 55.86 <sup>cd</sup>	17.78 ± 3.14 <sup>ab</sup>	1.77 ± 0.83 <sup>bc</sup>
	25	7.71 ± 1.14 <sup>bc</sup>	38.33 ± 6.24 <sup>abc</sup>	6.64 ± 2.34 <sup>bcd</sup>	1236.44 ± 562.49 <sup>d</sup>	269.00 ± 80.62 <sup>bc</sup>	16.64 ± 3.04 <sup>deg</sup>	1.77 ± 1.05 <sup>bc</sup>
	50	8.02 ± 8.02 <sup>bc</sup>	35.26 ± 6.12 <sup>cd</sup>	4.96 ± 1.98 <sup>ef</sup>	1291.24 ± 465.08 <sup>cd</sup>	237.84 ± 86.45 <sup>ef</sup>	17.93 ± 8.09 <sup>ab</sup>	1.61 ± 1.21 <sup>bcd</sup>
	75	6.26 ± 0.92 <sup>c</sup>	27.06 ± 3.51 <sup>f</sup>	4.28 ± 2.03 <sup>h</sup>	1228.85 ± 461.65 <sup>d</sup>	201.30 ± 75.85 <sup>g</sup>	16.86 ± 4.20 <sup>bcddefg</sup>	1.06 ± 0.73 <sup>e</sup>
Statistics	F	6.82	7.52	7.15	5.73	10.70	5.08	10.60
	P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

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Mean separation in a row by Least Significance Difference (LSD) test at 5% level. Means followed by the same letter are not significantly different at the 5% level. PL = plant length; NB = number of branching; NF = number of fruits per plant; FW = fruit weight; NS = number of seeds per fruit; 100-SW = 100 seeds weight; SY = seed yield

(flowering and fruit setting), varying from a mean of  $2.05 \pm 0.34 \text{ t ha}^{-1}$  (tendril) to  $1.55 \pm 0.34 \text{ t ha}^{-1}$  (fruit setting). A similar trend was observed with fruit mean weight per plant.

## DISCUSSION

Dual-purpose cropping for both leaf and seed production can be highly profitable, if leaves removal does not cause significant loss of seeds yield. Investigations on the gourd showed its susceptibility especially to late defoliation (Table 1). Results also indicated that the crop seemed to withstand moderate defoliation intensity applied at early stages, i.e. up to tendril stage. This result suggested that early defoliated plants had enough time to recover nutrients needed for growth and production. The crop did not recover when plants were defoliated at late growth stages. Such a phenomenon could result from two mechanisms (Ingram *et al.*, 1981): rapid recovery in stem and leaf growth, and enhancement of photosynthesis of previously shaded leaves to full sun. It has been shown in mustard (Khan and Lone, 2005) and grapevine (Hunter *et al.*, 1995) that early removal of leaves enhanced the emergence of new leaves with rapid growth, leading to leaf area increase. Such a compensatory effect was highlighted by the results of ANOVA indicating no significant difference between the control (% leaf removal) and the moderately defoliated plants (25% leaf removal) for seed yield and its components (Table 2).

The enhancement of photosynthetic activity in previously shaded leaves, due to their exposition to full sun could also explain the biomass recovery of early defoliated plants. Thus, these leaves were able to use all the light they intercepted, and up to fruit setting stage, they could contribute actively to plant biomass accumulation and increase in yield.

The increase in defoliation intensity proportionately reduced plant growth and production, with a sharp decrease in most of the traits examined (Table 2) at severe

defoliation intensity (75%). In many plants, intensive defoliation causes a steady reduction in the allocation of resources to stem and root growth, reducing as well the mobilisation of resources and re-establishment of plant biomass (Lattanzi *et al.*, 2004; Vargas-Ortiz *et al.*, 2013; Erbilgin *et al.*, 2014). It is well-known that severe defoliation has a direct effect on the mobilisation of C and N reserves and their supply to growing leaves. Defoliation has also an indirect effect on leaf and tiller morphogenesis, through its influence on the light environment within the canopy as well as plant responses to light signals (Baldissera *et al.*, 2014; Gastal and Lemaire, 2015). Overall, the results supported the hypothesis of complete yield recovery in crops defoliated in the vegetative stage, due to sufficient time and favorable conditions for adequate biomass accumulation to fulfil the yield potential.

The leaves of the gourd are widely used not only as food and feed, but also in pharmacology (Prajapati *et al.*, 2010; Roopan *et al.*, 2016). The results of this study showed that the gourd can be grown for multiple purposes. This may be a strategy to diversify income from the exploitation of the plant. Timing of cultivation and the trigger point for certain operations (fertilisation, weeding, phytosanitary treatment, harvest) are crucial for precision farming implementation. However, comprehensive studies to determine timing and conditions to initiate crop phytosanitary treatment are scanty (Follett and Hennessey, 2007; Iglesias *et al.*, 2010). The results of this study indicated the trigger point to treat gourd against leaves damaging pests to be about 25% of leaves defoliated, whatever the phenological stage of the plant.

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