



Sustaining maize (*Zea mays*) productivity through improved agronomic management practices under *jhum* ecosystems

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ABSTRACT

Maize (*Zea mays* L.) is an important crop cultivated in *jhum* farming (shifting cultivation) practiced in north-east India. However, productivity of maize in *jhum* is very low due to use of local cultivars and poor management practices. A participatory field trial was conducted in 2015–16 and 2016–17 to assess the impact of high yielding varieties/cultivars and improved management practices on maize productivity and soil fertility in farmer's *jhum* field of Ri-Bhoi District, Meghalaya. Nine cultivars/varieties of maize (Improved cultivars/varieties: Hemant, Vijay Composite, Megha Maize 1, Megha Maize 2, RCM 1-1, RCM 1-3, RCM 75 and local cultivars: SaruTangring and SaruBhoi) were evaluated under improved agronomic management practices (IAMP) and farmers' practice in a factorial randomized block design. Results revealed that number of seeds per cob, seed weight per cob and seed index were significantly higher under IAMP compared to that of farmers' practice during both the years. The IAMP produced significantly higher grain and stover yields of maize than farmers' practice. The maize variety Megha Maize 1 recorded significantly higher grain yield (3.15 and 2.92 t/ha in 2015–16 and 2016–17, respectively) than the rest of varieties/cultivars. The variety RCM 75 (7.13 t/ha) being at par with Megha maize 1 (6.83 t/ha) produced higher stover yield than others in year 2015–16. IAMP recorded significantly higher soil organic carbon, pH and available N, P, K over farmers' practice after two years. Thus, the study recommends adoption of improved agronomic management practices and high yielding cultivars like Megha Maize 1 and RCM 75 for sustaining soil fertility and enhancing productivity of maize under *jhum* farming in the north eastern region (NER) of India.

Keywords: Line sowing, Livelihood, Maize, Shifting cultivation, Soil fertility

The *jhum* farming (shifting cultivation) is a primitive agricultural system in tropics in which plots of land are cultivated temporarily after burning and clearing, and then abandoned for generating fertility (Layek *et al.* 2018). In north eastern region (NER) of India, the current practice of shifting cultivation is not scientific and is an unsustainable form of land use. About 85% of the total cultivation in north-east India was under shifting cultivation in 1990's which has reduced substantially to about 22% at present (0.50 Mha). It is a major option of livelihood for hilly and tribal small and marginal farmers where forest lands are

burnt and cleared for subsequent cultivation. Since the fallow period in *jhum* cycle reduced from 15–30 years in past to 3–6 years at present, the resilience of ecosystem has broken down and soil erosion, fertility depletion and deforestation, are taking place at an alarming rate (Arunachalam 2002).

Maize (*Zea mays* L.) occupies an important place under *jhum* farming in Himalayan region and is cultivated entirely under rainfed condition. Cultivation of traditional varieties, no manure or fertilizer application, improper crop establishment techniques, cultivation on sloping lands and associated accelerated soil erosion and traditional and minimal pest and disease management practices are the major limitations of *jhum* cultivation (Layek *et al.* 2018). The major causes of low productivity of maize in *jhum* land are phosphorus (P) deficiency, iron (Fe) and aluminium (Al) toxicity, and other soil acidity related nutritional deficiency (Manoj-Kumar *et al.* 2012). As a result, the maize productivity in *jhum* remains very low and rarely crosses 1.5 t/ha. The aim of the experiment was to develop sustainable soil fertility practices and crop establishment methods for maize cultivation in *jhum* land along with

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identification of suitable high yielding maize varieties/cultivars available in the region. The study also aims to create and increase awareness among *jhum* farmers to improve soil quality through integrated input management resulting in increased productivity and enhanced income of poor farmers of the region for better livelihood.

MATERIALS AND METHODS

A participatory field study was conducted for two consecutive years, i.e. 2015–16 and 2016–17 in farmer's *jhum* field at Sonidan village, Ri-bhoi District of Meghalaya, India. The experimental field was located at latitude 25°52'35" N, longitude of 92°07'37" E and an elevation of 926 m amsl. The experimental site received a substantial amount of rainfall of 2217 mm (average of 2015–16 and 2016–17). While the majority of rainfall was received in the months of May–October and minimal amount of rain was received during November–March. Data on average monthly weather parameters during the crop growth period in year 2015–16 and 2016–17 is presented in Fig 1. The daily mean temperature during the *kharif* period (May–October) ranged from 23–32°C. The *jhum* land was cleaned in the month of December, 2014 and prepared for sowing in the month of April 2015. The experimental field had pH 4.57, high organic carbon (2.64%), low available nitrogen (270.6 kg N/ha) and phosphorus (Bray; 30.25 kg P₂O₅/ha) and medium potassium (253.7 kg K₂O/ha). The experiment was conducted under factorial randomized block design (FRBD) and replicated thrice. Nine cultivars/varieties of maize [Improved: Megha Maize 1 (DA 61A), Vijay Composite, Hemant, Megha Maize 2 (RCM 76), RCM 1-1, RCM 1-3, RCM 75, and local cultivar: SaruTangring, and SaruBhoi] were screened under improved agronomic management practices (IAMP). The IAMP practices for maize in *jhum* land involved doses of manure (2 t/ha) and fertilizer application @40:30:20 kg N, P₂O₅, K₂O/ha (50% of recommended for terraced land maize cultivation), line sowing of maize at 50 cm apart along the contour, furrow lime application @500 kg/ha, two hand weeding and need based insect-pest and disease management, etc) and the results obtained were compared with farmers' practice (random dibbling of seeds, no manure/fertilizer application, one hand weeding, no soil and water conservation practices, no plant protection measures, etc). Seeds of maize were planted in fourth week of April while maintaining 50 cm row to row and 25 cm plant to plant spacing under IAMP, while in farmers' practice 3–4 seeds were randomly dibbled without any fixed spacing. Insect and disease problems were within the threshold limits and hence no measures were required for their management. By growing hedgerow leguminous *Tephrosia* spp. at 10 m interval along the contour, the slopes of *jhum* land were divided into small strips under IAMP practices to produce

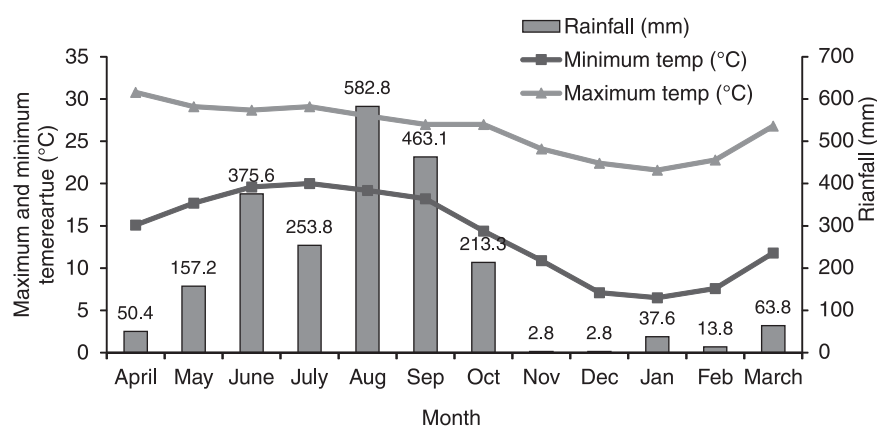


Fig 1 Average monthly weather parameters of the ICAR Research Complex for NEH Region, Umiam during 2015–16 and 2016–17.

soil enriching green leaf manure and minimizing soil erosion through soil and water runoff. The full dose of phosphorus (P) and potassium (K) was supplied as basal at the time of planting furrows through single super phosphate (SSP) and muriate of potash, respectively. The nitrogen (N) requirement was supplied in the form of urea in three split doses, i.e. 1/3rd as a basal (time of sowing), 1/3rd at knee height stage, and 1/3rd at tasselling stage. Two hand weeding were used at 20 and 45 days after sowing (DAS).

Five plants of maize were randomly selected from each plot for taking observations on yield attributes at harvest. The yield of maize was recorded from the net plots as per the standard procedures. Initial and final soil samples after two years of experiment were collected from 0–15 cm surface soil. The soil organic carbon (SOC) concentration was estimated through the method of Walkley and Black (Nelson and Sommers 2005). Soil pH was measured with the help of a digital pH meter by using 1:2.5 soil:water solution (Jackson 1973). While the available N in soil was estimated by alkaline permanganate method (Subbaiah and Asija 1956), available P were measured using spectrophotometer through extraction method of Bray's (Bray and Kurtz 1945).

All the data recorded/estimated in the experiment were statistically analyzed through analysis of variance (ANOVA) technique and F-test was used for testing their significance (Gomez and Gomez 1984). To evaluate the differences between treatment means, standard error of means (SEm±) as well as critical differences (CD) were determined at 5% level of significance for all the parameters studied.

RESULTS AND DISCUSSION

Yield attributes: The two years experiment on *jhum* revealed that, number of seeds per cob, seed weight per cob and seed index of maize were significantly higher under IAMP as compared to those in farmers' practice (FP) during both years of study. Most of the yield attributes are relatively higher in year 2015–16 as compared to 2016–17. Since, soil fertility status declines over the years after starting cultivation in *jhum* land especially under farmers' practice (FP), yield attributes decline in successive years if sufficient nutrients are not provided. The number of rows/

cob of maize was also significantly higher in IAMP in the year 2015–16 than FP. Among varieties evaluated under *jhum* ecosystem, Megha Maize 1 and RCM 75 gave better performance in terms of yield attributes as compared to other varieties (Table 1). Number of seeds/cob produced in year 2015–16 was the highest by variety Megha Maize 1 (303.5) which was statistically at par with variety RCM 75 (300.6). Local cultivar SaruTangring gave bolder seeds followed by Megha Maize 1 and RCM 75 in the year 2015–16 than others. Whereas, RCM 75 produced bolder seeds, weight of which were statistically at par with Megha Maize 1 and SaruTangring in the year 2016–17. Proper spacing, adequate nutrition, liming and low weed pressure under IAMP might have facilitated effective and uniform utilization of space, sunlight and nutrients, leading to better growth, yield attributes and development than FP. Integrated application of manure as well as fertilizers to maize might have improved soil properties and efficient utilization of nutrients by plants which subsequently helped in improving the yield attributes of maize (Das *et al.* 2010). Liming improved soil pH, other soil properties especially availability of nutrients and hand weeding reduced competition for resources with the weeds (Ramesh *et al.* 2014). Enhancement in yield attributes and yield of crops due to improvement in soil properties under integrated application of low dose of fertilizer and manure over individual application of inorganic fertilizer and control (no manure or fertilizer) have been previously recorded by other researchers (Das *et al.* 2010, Ejigu *et al.* 2021, Singh *et al.* 2022).

Grain and stover yield: The IAMP gave significantly higher grain yield (Table 2) of maize (3.13 and 2.85 t/ha for year 2015–16 and 2016–17, respectively) than FP

(2.03 and 1.77 t/ha for year 2015–16 and 2016–17, respectively). The stover yield of maize under IAMP was also significantly higher than FP during both the experimental years. Improvement in grain and stover yields of maize are attributed to improvement in yield attributes under IAMP. Varieties differed statistically with respect to grain yield in the year 2015–16 and 2016–17. For example cv. Megha Maize 1 produced significantly higher grain yield (3.15 and 2.92 t/ha in 2015–16 and 2016–17, respectively) than rest of the eight maize varieties/cultivars. RCM 75 produced comparable yield with Megha Maize 1 in both the years (3.08 and 2.80 t/ha in 2015–16 and 2016–17, respectively). Stover yield of maize was also significantly influenced by different cultivars/varieties tested under *jhum*. The variety RCM 75 produced the highest stover yield (7.13 t/ha) which was at par with RCM 1-3, Megha Maize 1 and RCM 1-2 in 2015–16. All these stover yields were significantly higher than those obtained with Vijay Composite and Megha Maize 1 in 2015–16. However, in 2016–17, stover yield of RCM 75 (7.15 t/ha) was the highest which was at par with RCM 1-3 (7.10 t/ha). The variety Megha Maize 1 recorded higher harvest index (31.4%) but remained at par with varieties Megha Maize 2 (30.2%) and SaruBhoi (29.5%) during the year 2015–16. Furrow liming is known to effectively ameliorate soil acidity by raising the pH, enhance nutrient availability and subsequently enhance the plant growth as well as productivity (Ramesh *et al.* 2014). Integrated application of low dose of fertilizer, manure along with liming improved soil properties (Das *et al.* 2010), released essential nutrients available to crop slowly and steadily throughout its growth period leading to enhancement in biomass and grain productivity (Ramkrushna *et al.* 2018).

Table 1 Effect of cultivation practices and varieties on yield attributes of maize

Treatments	No. of rows/cob		No. of seeds/cob		Seeds weight/cob (g)		Seed index (g)	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
<i>Cultivation practices</i>								
Improved practice	11.7	11.0	301.5	269.1	72.4	60.6	24.0	23.0
Farmers' practice	11.2	10.4	235.2	209.9	50.2	46.1	22.1	21.7
SEm±	0.03	0.03	1.51	1.41	0.47	0.30	0.11	0.08
CD (P=0.05)	NS	0.10	4.34	4.06	1.35	0.87	0.32	0.24
<i>Varieties</i>								
Hemant	11.3	10.9	225.2	222.5	51.3	46.0	23.6	21.6
Vijay Composite	11.2	10.8	274.5	222.9	63.4	48.2	21.3	19.9
Megha Maize 1	11.8	11.5	303.5	280.3	76.0	67.4	23.8	23.7
RCM 1-1	11.6	11.0	278.6	264.8	62.8	59.5	19.7	20.5
RCM 1-3	11.2	10.7	255.7	262.4	61.2	51.3	21.8	21.2
RCM 75	12.5	11.5	300.6	272.5	75.4	64.9	25.7	23.7
Megha Maize 2	11.4	11.2	264.9	246.8	56.5	53.4	25.1	23.6
SaruTangring	10.7	9.3	241.7	221.3	52.4	51.9	24.9	26.5
SaruBhoi	10.9	9.1	270.8	162.4	52.6	37.1	21.5	20.4
SEm±	0.16	0.15	6.79	6.35	2.11	1.37	0.50	0.37
CD (P=0.05)	NS	0.43	19.51	18.25	6.06	3.93	1.45	1.05

Table 2 Effect of cultivation practices and varieties on yield of maize

Treatments	Grain yield (t/ha)		Stover yield (t/ha)		HI (%)	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
<i>Cultivation practices</i>						
Improved practice	3.13	2.85	6.78	7.31	31.6	28.1
Farmers' practice	2.03	1.77	5.68	5.44	26.3	24.5
SEM±	0.01	0.01	0.03	0.04	0.14	0.13
CD (P=0.05)	0.03	0.04	0.08	0.11	0.41	0.38
<i>Varieties</i>						
Hemant	2.32	2.15	5.63	4.90	29.2	30.5
Vijay Composite	2.39	2.04	6.82	6.61	26.0	26.6
Megha Maize 1	3.15	2.92	6.93	6.88	31.3	31.4
RCM 1-1	2.83	2.12	6.48	6.84	30.4	29.3
RCM 1-3	2.57	2.31	6.26	7.10	29.1	26.6
RCM 75	3.08	2.80	7.13	7.15	30.2	30.1
Megha Maize 2	2.40	2.37	5.79	5.63	29.3	29.7
SaruTangring	2.29	2.05	5.94	5.97	27.8	27.6
SaruBhoi	2.27	2.02	5.42	4.92	29.5	29.1
SEM±	0.05	0.06	0.13	0.17	0.64	0.61
CD (P=0.05)	0.14	0.18	0.36	0.49	1.84	1.81

HI, Harvest index.

Superiority of RCM 75, RCM 1-3 and Megha Maize 1 cultivars of maize under upland ecosystems of Meghalaya has been previously reported by Layek *et al.* (2016).

Soil fertility: Different management practices had a significant effect in respect to SOC, soil pH, available N, P and K of soil during both the years of cultivation (Table 3). There was a reduction in available N, P and K content in soil

after two years of experimentation owing to the absorption of these nutrients for the crop growth and other losses. Decrease in N, P, K and SOC was less under IAMP compared to that under farmers' practice. IAMP resulted in significantly higher available N, P, K, SOC and pH over farmers' practice in both the years. Except N, no other nutrients and SOC and pH were significantly influenced by the varieties/cultivars.

Table 3 Effect of cultivation practices and varieties on soil available N, P, K, SOC and pH (0–15 cm soil depth)

Treatments	Available N (kg/ha)		Available P ₂ O ₅ (kg/ha)		Available K ₂ O (kg/ha)		SOC (%)		pH	
	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17	2015–16	2016–17
<i>Cultivation practices</i>										
Improved practice	258.2	247.2	30.7	28.2	243.6	238.2	2.52	2.47	4.72	4.69
Farmers' practice	241.0	235.9	26.8	26.0	235.2	231.0	2.36	2.24	4.49	4.50
SEM±	0.45	0.57	0.10	0.05	0.44	0.26	0.00	0.01	0.01	0.01
CD (P=0.05)	1.29	1.63	0.30	0.15	1.26	0.77	0.01	0.02	0.02	0.03
<i>Varieties</i>										
Hemant	257.2	249.5	27.0	26.5	238.4	234.9	2.43	2.31	4.65	4.54
Vijay Composite	251.1	242.3	28.0	25.8	237.7	233.6	2.48	2.35	4.60	4.59
Megha Maize 1	244.6	231.7	27.2	26.8	242.4	235.0	2.37	2.34	4.61	4.55
RCM 1-1	240.4	233.5	29.3	27.9	243.3	231.7	2.47	2.43	4.60	4.56
RCM 1-3	252.0	252.5	28.1	27.0	237.6	234.2	2.43	2.39	4.63	4.62
RCM 75	250.2	232.7	30.9	27.5	242.4	233.3	2.42	2.44	4.52	4.66
Megha Maize 2	241.4	231.7	29.1	27.2	238.1	232.9	2.52	2.44	4.63	4.62
SaruTangring	241.1	244.2	29.5	27.6	237.1	237.0	2.41	2.40	4.64	4.59
SaruBhoi	268.0	256.0	29.5	27.5	237.6	238.3	2.44	2.37	4.58	4.62
SEM±	2.02	2.56	0.46	0.24	1.97	1.19	0.02	0.03	0.03	0.04
CD (P=0.05)	5.80	7.36	NS	NS	NS	NS	NS	NS	NS	NS

The highest N content in soil (268.0 and 256.0 kg/ha, for the year 2015–16 and 2016–17, respectively) was observed under variety SaruBhoi which significantly differed with variety Megha Maize 1 in the year 2015–16 and 2016–17. There was no significant difference in soil SOC and pH in soils under different varieties in both the years. Liming along with integrated application of organic and inorganic fertilizer has been reported to ameliorate soil acidity induced fertility issues and enhance the availability of essential nutrients for plant growth and development (Manoj-Kumar *et al.* 2012). Application of lime along with fertilizer and organic manure supplies basic cations like Ca^{2+} and Mg^{2+} and increase the soil pH (Fageria *et al.* 2007) and anions (CO_3^{3-}) (Ramkrushna *et al.* 2018). Integrated application of fertilizer, organic manure and lime, and hand weeding and need based pest management under IAMP might have led to enhanced SOC concentrations and overall improvement in soil properties as compared to FP (Layek *et al.* 2016). IAMP also resulted in high above and below ground biomass production which contributed to SOM build up due to decomposition of detritus and root biomass (Das *et al.* 2010, Manoj-Kumar *et al.* 2012, Ramesh *et al.* 2014, Ramkrushna *et al.* 2018). Application of manures and lime in the soil releases organic acids, which suppress Al content in the soil through chelation process and increase pH and reduces exchangeable Al in soil (Onwonga *et al.* 2008). Increase in the SOC with combined application of fertilizer and organic manure was also reported by Ramkrushna *et al.* (2022).

The study suggests that higher crop and soil productivity of maize in *jhum* fields can be obtained through adoption of adequate high yielding varieties/cultivars like Megha Maize 1, RCM 75 along with integrated application of low dose of fertilizer, manure, lime and two hand weeding. Soil and water conservation practices like adoption of leguminous hedge row at a regular interval across the slope, organic matter application and liming contribute to a great extent for improving soil fertility and sustainable crop production in the NER of India.

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REFERENCES

- Arunachalam A, Khan M L and Arunachalam K. 2002. Balancing traditional *jhum* cultivation with modern agroforestry in eastern Himalaya – A biodiversity hot spot. *Current Science* **83**: 117–118.
- Das A, Patel D P, Munda G C and Ghosh P K. 2010. Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*)—mustard (*Brassica campestris*) cropping system. *Indian Journal of Agricultural Sciences* **80**(1): 85–88.
- Ejigu Workineh, Yihenew G. Selassie, Eyasu Elias and Matebe Damte. 2021. Integrated fertilizer application improves soil properties and maize (*Zea mays* L.) yield on Nitisols in Northwestern Ethiopia. *Heliyon* **7**(2): e06074.
- Gomez K A and Gomez A A. 1984. *Statistical procedure for agricultural research*, 2nd edn. International Rice Research Institute, John Wiley and Sons, New York, USA.
- Jackson M L. 1973. *Soil Chemical analysis*. Prentice Hall of India Pvt. Ltd. New Delhi.
- Layek J, Ramkrushna G I, Suting D, Ngangom B, Krishnappa R, De U and Das A. 2016. Evaluation of maize cultivars for their suitability under organic production system in North Eastern Hill Region of India. *Indian Journal of Hill Farming* **29**(2): 19–24.
- Layek J, Das A, Ramkrushna G I, Sarkar D, Ghosh A, Zodape S T, Lal R, Yadav G S, Panwar A S, Ngachan S and Meena R S. 2018. Seaweed extract as organic bio-stimulant improves productivity and quality of rice in eastern Himalayas. *Journal of Applied Phycology* **30**(1): 547–558.
- Manoj-Kumar, Khan M H, Singh P, Ngachan S V, Rajkhowa D J, Kumar A and Devi M H. 2012. Variable lime requirement based on differences in organic matter content of iso-acidic soils. *Indian Journal of Hill Farming* **25**(1): 26–30.
- Nelson D W and Sommers L E. 2005. Total carbon, organic carbon and Organic Matter. *Analysis of Soil and Plants Chemical Methods*. Spark D L (Eds). SSSA Book Series 5, Soil Sci. Soc. Am., Am. Soc. Agron. Inc., Wisconsin, USA.
- Bray R H and Kurtz L T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* **59**: 39–45.
- Onwonga R N, Lelei J J, Freyer B, Friedel J K, Mwonga S M and Wandhawa P. 2008. Low cost technologies for enhancing N and P availability and maize (*Zea mays* L.) performance on acid soils. *World Journal of Agricultural Sciences* **4**(5): 862–73.
- Ramesh T, Hazarika S, Choudhury B U, Manoj-Kumar, Verma B C, Rajasekar K and Ngachan S V. 2014. Soil fertility changes under long-term integrated nutrient management practices on acid soils of Meghalaya. *Indian Journal of Hill Farming* **27**(1): 1–10.
- Ramkrushna G I, Das A, Layek J, Babu S, Verma B C, Patel D P, Krishnappa R, Savita and Ngachan S V. 2018. Productivity, economics and soil fertility under different maize (*Zea mays*) varieties as influenced by soil ameliorating practices in North Eastern hill region of India. *Indian Journal of Agricultural Sciences* **88**(5): 766–70.
- Ramkrushna G I, Das A, Layek J, Verma B C, Babu S, Mohapatra K P and Shahane A A. 2022. Assessing maize based cropping systems for higher productivity and income under shifting cultivation in eastern Indian Himalayas. *Indian Journal of Soil Conservation* **50**(2): 101–06.
- Singh H V, Jat R S, Choudhary R L, Rathore S S, Meena M K and Rai P K. 2022. Contemporary nitrogen management in maize (*Zea mays*)—Indian mustard (*Brassica juncea*) cropping system for maximizing yield, water productivity and profitability. *The Indian Journal of Agricultural Sciences* **92**(11): 1381–85.
- Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in rice soils. *Current Science* **25**: 259–60.