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Inheritance of andromonoecy in ridge gourd (*Luffa acutangula* Roxb.) L.

Ridge gourd [*Luffa acutangula* (Roxb.) L.], is one of the most important vegetables grown throughout the year in all the tropical regions especially in Asian and African countries. It is rich in vitamin A, C and iron[1]. A variety of sex forms, with different genetic mechanisms, were reported in cucurbitaceous crops[2]. Monoecy is governed by a single dominant gene in the monoecious versus andromonoecious sex forms of watermelon and *Cucumis ficifolius*[3,4]. In contrast, andromonoecy was reported to be controlled by two linked dominant genes in *tibish* group of melon[5]. Also, the digenic nature of inheritance of monoecious, andromonoecious, gynomonoecious/gynoecious and hermaphrodite conditions showing F_2 ratio of 9 : 3 : 3 : 1 was reported in *Cucumis melo*[6] and *Luffa acutangula*[7,8].

In the ridge gourd germplasm, IIHR-43 (IC110893) maintained in the laboratory at ICAR-IIHR, an andromonoecious plant which bore male and hermaphrodite flowers on the same plant was noticed during 2010. This variant was designated as 'Andromon-43' (AM-43). It was found to breed genetically true to type in subsequent generations of selfing, but produced short fruits.

Observations on morphological traits of AM-43 and the normal monoecious types are presented in Table 1. It is interesting to note that the AM-43 was accompanied by certain features, but phenotypically distinct from the monoecious lines. The observations revealed that flowering in AM-43 was early and the first female flower emerged at lower nodes (5.9) compared to monoecious (9.5–13.9 node). Further, AM-43 produced very small leaves (179.1 cm^2 versus 311.6–370.2 cm^2), an oval and short ovary (Figure 1 *d*) and well-developed anthers encircling the stigma (Figure 1 *c*). AM-43 produced a larger number of fruits/plant (52.4) compared to monoecious types (5.4–10.6). However fruits developing on AM-43 were extremely short (5.4 cm versus 30.1–45.2 cm; Figure 1 *f* and *g*).

To understand the inheritance of andromonoecy in ridge gourd, crosses were effected during 2012 monsoon. The andromonoecious line, AM-43 was crossed as male parent with three normal monoecious lines, viz. IIHR-6, IIHR-70 and IIHR-73. A total of 24 F_0 seeds from well-developed fruits were extracted to raise F_1 generation of each cross in the

Table 1. Mean performance of andromonoecious and monoecious lines with respect to leaf, flower and yield parameters in ridge gourd

Germplasm	Days taken for the first female flower appearance	Node number for the first female flower appearance	Leaf size (cm^2)	Ovary length (cm)	Fruit length (cm)	Fruit girth (cm)	Number of fruits/plant	Fruit weight (g)	Yield/plant (kg)
'Andromon-43'	42.6	5.9	179.1	3.8	5.4	13.3	52.4	42.2	2.2
'IIHR-6'	55.9	13.9	311.6	8.3	35.0	12.0	10.6	187.4	2.0
'IIHR-70'	46.7	9.5	370.2	7.2	30.1	13.3	5.4	191.6	1.1
'IIHR-73'	53.8	12.0	369.8	8.1	45.2	12.7	7.5	194.9	1.4
Mean	49.8	10.3	302.0	6.8	28.9	12.8	18.9	154.0	1.7
S.Em ±	1.2	0.9	0.7	0.7	2.1	0.4	2.4	4.3	0.4

Table 2. Segregation pattern of monoecious and andromonoecious sex forms in F_2 and BC_1 generations in ridge gourd

Cross	Number of seeds sown	Number of plants obtained	Number of monoecious plants	Number of andromonoecious plants	Observed ratio	Chi-square value	Probability (%)
F_2 generation							
'IIHR-6' × 'Andromon-43' (AM-43)	196	73	57	16	3.56 : 1	0.369	0.50–0.75
'IIHR-70' × 'AM-43'	196	109	80	29	2.75 : 1	0.149	0.50–0.75
'IIHR-73' × 'AM-43'	196	71	52	19	2.73 : 1	0.117	0.75–0.90
Total	588	253	189	64	2.95 : 1	0.011	0.90–0.95
BC_1 generation							
('IIHR-6' × 'AM-43') × 'AM-43'	49	28	7	21	0.33 : 1	7.000	0.10
('IIHR-70' × 'AM-43') × 'AM-43'	49	17	11	6	1.83 : 1	1.470	0.10–0.25
('IIHR-73' × 'AM-43') × 'AM-43'	49	17	10	7	1.42 : 1	0.529	0.25–0.50
Total	147	62	28	34	0.82 : 1	0.580	0.25–0.50

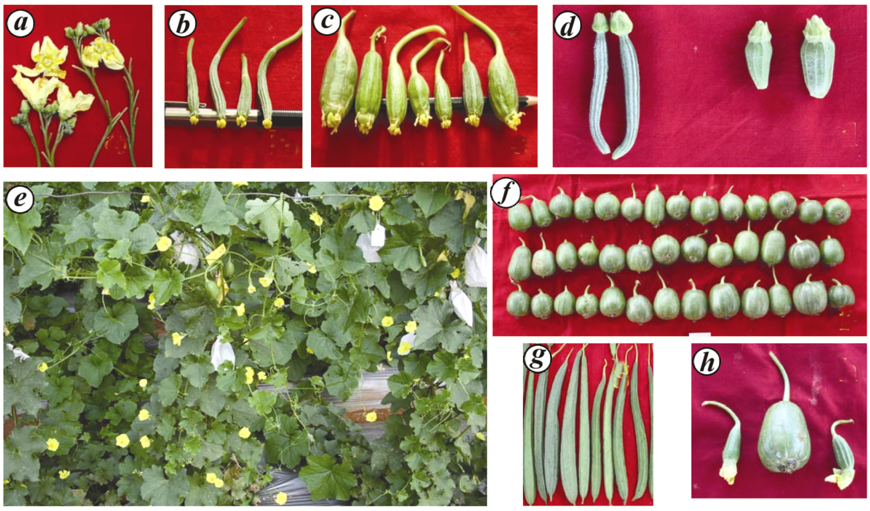

Figure 1 ***a–h***. Morphological composition of flower and fruit shape of andromonoecious and monoecious forms in *Luffa acutangula*. ***a–d***, Flower morphology: ***a***, staminate flower; ***b***, pistillate flower; ***c***, close up of matured hermaphrodite flower of Andromon-43; ***d***, comparison of ovary of pistillate and hermaphrodite flower; ***e***, plant morphology of Andromon-43. ***f–g***, Fruit shape: ***f***, andromonoecious form; ***g***, normal; ***h***, hermaphrodite flower and fruit of Andromon-43.

summer, 2013. All the 45 F_1 plants raised from the 72 seeds were monoecious in nature with floral characteristics similar to their respective monoecious female parents.

In each of the 3F_1 families, five plants were selected and in each plant, two pistillate flowers were selfed. The seeds thus obtained were used to raise F_2 generation. Further another five pistillate flowers from another set of five F_1 plants were backcrossed with AM-43 to get BC_1 seeds. All the fruits developed in F_1 plants were similar in shape to that of their respective female parents, and contained abundant normal seeds.

The F_2 and BC_1 generations were grown during Rabi-summer, 2013–14. A random sample of 196 seeds each from the three F_2, and 49 seeds each from the three BC_1 generations, were taken and sown in the seedling trays. From three F_2 and BC populations, a total of 253 F_2 and 62 BC_1 seedlings were transplanted at the two-true leaf stage, to well prepared plots.

The expression of sex form, flower and fruit morphology in F_1 generation showed complete dominance of monoecious sex habits over andromonoecious sex, medium long to long fruit shape to oval fruit shape, and small blossom scar over large blossom scar (Figure 1 *h*). The segregating patterns of the two sex forms in F_2 and BC_1 generations are given in Table 2. The chi-square values suggested that the segregation for monoecy to andromonoecy was a good fit for 3 : 1 ratio ($P = 0.90–0.95\%$) in F_2 and for 1 : 1 ratio ($P = 0.25–0.50\%$) in BC_1. This suggested that andromonoecy is controlled by a single gene and is recessive to monoecy in ridge gourd. Similar inheritance pattern has been reported for these sex forms in bottle gourd by Singh *et al.*[8]. Thakur[9] reported that both in intervarietal crosses of *L. acutangula* and in interspecific crosses between *L. acutangula* and *L. cylindrica*, sex form was found to be digenically inherited. Based on the assumption that the basic sex in angiosperms is hermaphrodite, it was postulated that sex expression in *Luffa* is controlled by two independent suppressor genes, *A* and *G*, the former suppressing the male organ in the solitary flowers and the latter suppressing the femaleness of the racemes[9]. When both these dominant suppressing genes were present, the plant showed monoecism. In the presence of *G* and recessive gene '*a*', the plant becomes andromonoecious. Based on this, AM-43 sex form can be genetically represented as 'aaGG'.

Ridge gourd is a cross-pollinated crop because of its monoecious flowering habit and pollination is effected by honey bees. Successful cultivation of ridge gourd in rainy season is limited by high incidence of downy mildew disease, and poor fruit set due to pollen washing out. However, better fruit set is possible in plants exhibiting andromonoecy, due to presence of hermaphrodite flowers, as they have the ability to set fruits following self/cross pollination. Further growing such plants in polyhouses during rainy season, should help protect crops from downy mildew as well as excess rains. But andromonoecious lines produce small fruits. Hence, to make commercial cultivation of andromonoecious lines feasible, AM-43 will be useful in introgressing its andromonoecious gene into the long fruited monoecious lines to develop andromonoecious varieties with increased fruit length and more number of fruits. The high yield potential andromonoecious ridge gourd varieties thus developed, should be suitable either for polyhouse cultivation or for rainy season cultivation in open conditions.

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Feasibility of quinoa cultivation in Ladakh

Situated at an altitude of about 3000 m amsl, Ladakh, J&K, India is known for its extremely harsh climate for crop growth. Extremely low temperatures, extreme aridity, large diurnal variation and uncertain weather changes are characteristic features of the climate in Ladakh. These coupled with agriculturally marginalized land which is poor in its physical, chemical and biological properties have resulted in an inherently poor agriculture production system. Only a handful of field crops like barley and to some extent wheat, mustard and pulse pea which can mature within 120–150 days of the cropping window available during May–September are grown traditionally. Productivity of these crops remains low due to poor supply of input owing mainly to physical isolation from the mainland and poor economic condition of the peasants. Any alternative field crop that has the potential to produce better yield than these traditional crops, that too with limited input, is worth experimenting in order to give an option to farmers in the region. One such crop, which also has promising world market, is quinoa.

Quinoa (*Chenopodium quinoa*) – a plant of South American origin – is in demand worldwide due to its high nutritional value and its ability to grow in extremely poor conditions. It is a pseudo cereal whose grains can be used as a substitute for cereals (carbohydrate 71%; calories 350 per 100 g)[1]. Besides providing energy, its grain is rich in protein (13.81%–21.9%) of high quality. In fact quinoa grain is the only food of plant origin that provides all essential amino acids for human nutrition standards established by FAO[1]. What is more, the essential amino acids that are present in quinoa are located in the nucleus of the grain, not in the exosperm or hull as in case of rice or wheat, and thus remain preserved in the grain even after processing. Furthermore, due to its high total dietary fibre (TDF 6% of the total weight of the grains), quinoa intake promotes intestinal transit, eliminates toxins and waste products that can damage the body and regulates cholesterol. Quinoa also helps reduce LDL (or bad cholesterol) in the body and increase HDL (good cholesterol) due to its omega 3 and omega 6 fatty acid content[1].

The crop has remarkable adaptability to different agro-ecological regions. It