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BIOSYSTEMATICS OF INDIAN PLANTS IV: *PORTULACA OLERACEA* AND *P. QUADRIFIDA* IN PUNJAB

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ABSTRACT

A large collection of two polymorphic weeds, *Portulaca oleracea* Linn. and *P. quadrifida* Linn., originating from diverse sources, was cultivated under uniform conditions. This experiment revealed the extent and nature of genetic variation in the two species. In the former there were found three qualitatively distinguishable variants all at hexaploid (n=27) level, while in the latter there were only two quantitatively distinct variants at 6x (n=27) and 12x levels. All these have been evaluated biosystematically.

INTRODUCTION

According to Hooker (1872) and Kashyap & Joshi (1936), *Portulaca oleracea* Linn. and *P. quadrifida* Linn. are two species of the genus, that commonly grow wild in the Punjab Plains. These species, particularly the former, occupy very diverse habitats and are polymorphic. A large number of collections of these species from diverse habitats were cultivated under uniform conditions. This removed all chances for environmental modifications, and genetic variation became apparent. These experiments revealed that in *P. oleracea* three qualitatively distinct morphological types occur commonly in the Punjab, while in *P. quadrifida* there occur two types distinct only in quantitative characters. A critical study was undertaken. *P. oleracea* was also sampled with collections outside the Punjab, one from Sacavem (Portugal) and several others from Gauhati (Assam), Calcutta, Delhi and Ajmer.

METHODS

Genus *Portulaca* is indeed a very unfavourable cytological material. Most of the previous workers have made studies from sectioned material (Cooper, 1935, 1940; Steiner, 1944; partly also Sharma and Bhattacharya, 1955). However, the present work is entirely based on squash preparations of both root-tips and pollen mother-cells.

Text-figures of chromosomes were drawn at a uniform magnification of ×2,600, but have been reduced to half during publication.

OBSERVATIONS

Portulaca oleracea Linn.

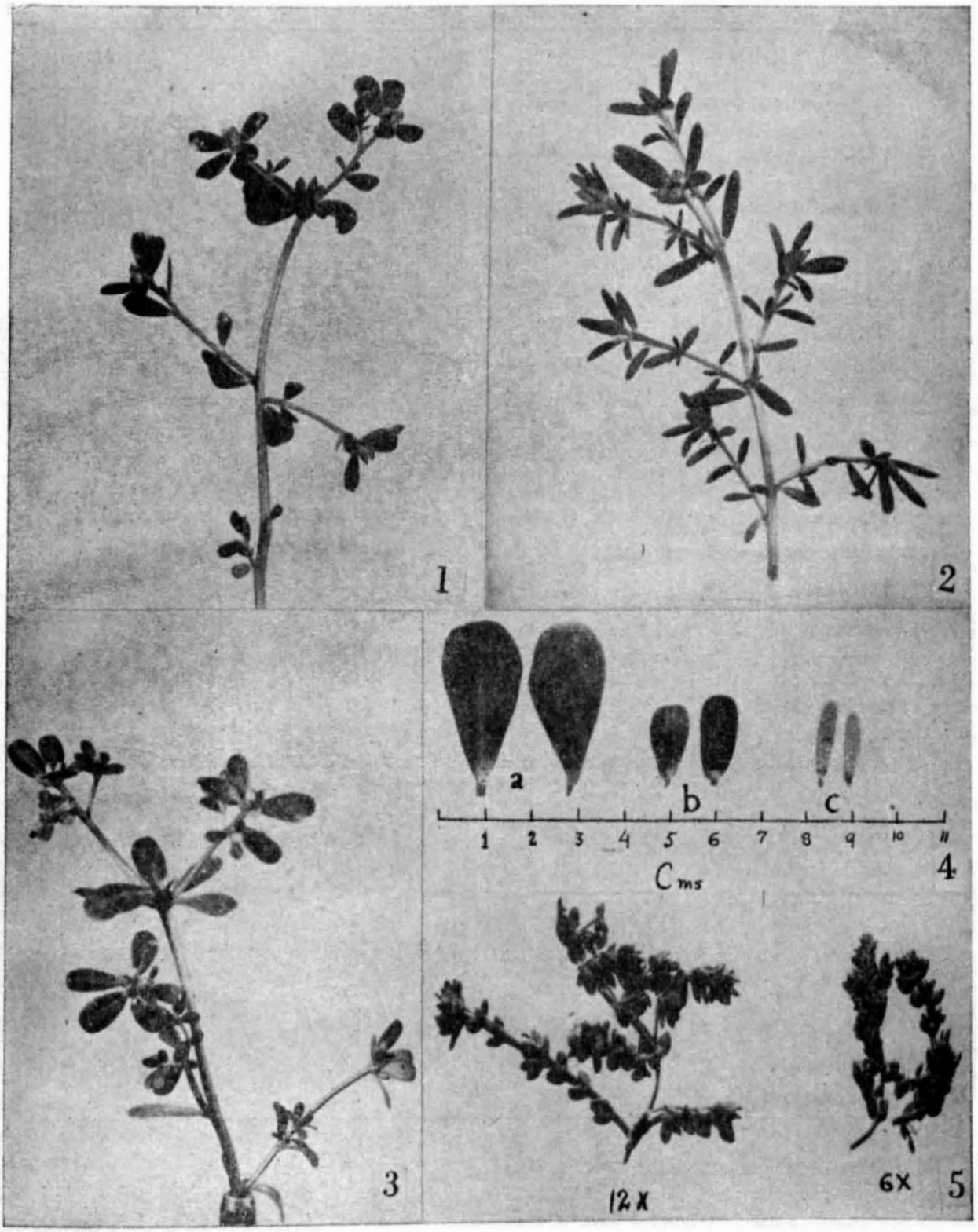
Basically this is a tropical species and grows in all warm countries. It has extended even to the temperate regions of the world and is now almost a cosmopolitan weed. In India it is one of the very common summer weeds, and extends from the plains and hills in Deccan Peninsula to an altitude of 1460 m in the Himalayas. In Kashmir it often grows near habitations even at an altitude of 1800 m. Besides growing wild, this species is often cultivated as a pot herb, particularly in Northern India.

As mentioned earlier, three distinct morphological types can be identified, which breed true to their characters. The first of these is the most common and often a troublesome weed. It is suberect to procumbent and has more or less obovate leaves* (Fig. 1). Often associated with this, is the second type, which is invariably suberect, but has narrowly-obovate leaves (Fig. 2). Both these are wild, but the third type is cultivated and is invariably erect with rather large, more or less obtriangular leaves (Fig. 3). Hereafter, the three will be referred to as obtriangular (a), obovate (b), and narrowly-obovate (c) types respectively (Fig. 4).

As is evident the obtriangular type is a cultigen, while the other two types, particularly the more common obovate type, grow in diverse habitats, ranging from favourable to those which are ordinarily inhospitable. The morphological characters are summarized in Table I and are briefly discussed below.

Morphology: The members of this complex are subsucculent and glabrous summer annuals. The branching may be opposite or alternate. Obtriangular type is about 45 cm tall and nearly 1.5 cm thick at the ground level. Obovate type is at times somewhat ascending and is hardly 30 cm long, but is rather slender, being about 0.3-0.5 cm thick at the ground level. It branches rather profusely. Narrowly-obovate type is also suberect, it is about 20 cm tall, but is somewhat robust in comparison to the obovate type. The former is about 0.6-0.75 cm

*The chart published in Taxon, 1962, 9 : 3 (June) was consulted for outline of the leaves.



Figs. 1-3. *P. oleracea* : Obovate, narrowly-obovate and obtriangular types. 1-2. ×1 and 3. ×4/5. Fig. 4. Leaves of obtriangular (*a*), obovate (*b*) and narrowly-obovate (*c*) types of *P. oleracea*.

Fig. 5. *P. quadrifida* : Hexaploid and dodecaploid types ×4/5.

TABLE I

Characters of *P. oleracea* complex

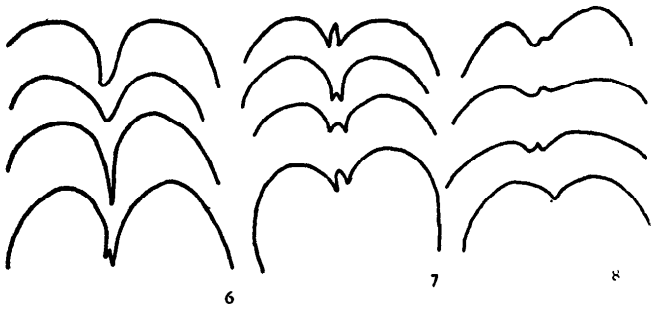
Characters	Obtriangular	Obovate	Narrowly-obovate
STEM			
Plant size (cm)	45	30	20
Stem thickness at ground level (cm)	1-1.5	0.3-0.5	0.6-0.75
Branching pattern	Opposite beneath and alternate above	Same	Opposite and alternate
Colour of the stem	Greenish pink	Often reddish especially in plants that are exposed	Greenish
LEAF			
Length (cm)	2.5-4.5	1-2	0.5-2.5
Breadth (cm)	1-2	0.5-1	0.1-0.3
Thickness (μ)	330	198	792
Shape	Obtriangular	Obovate	Narrowly-obovate
Apex	Obtuse but slightly depressed in the middle	Same	Obtuse
Petiole (cm)	0.1-0.3	0.1-0.2	0.1-0.2
Stomatal size (μ)	35×21	39.5×29.5	39.5×29.5
FLOWER (measurements in cm)			
Diameter	0.7	0.6	0.5
Length	0.7	0.5	0.5
Sepal length	0.3	0.5	0.3
Sepal breadth	0.25	0.3	0.3
Petal length	0.6	0.5	0.4
Petal breadth	0.3	0.25	0.20
Apex of petal	Deeply notched, mucro rather indistinct when present	Notched with a distinct mucro	Very shallowly notched, mucro rather indistinct when present
Stigma	5-fid	Same	Same
Pollen size (μ)	79.2	66	79.2
Percentage of stainable pollen	90	100	80
SEED			
Number of seeds per capsule	20-36	32-55	55-75
Percentage of good seed	64-80-100	90-100	98-100
Seed length (μ)	990	726	706
Seed breadth (μ)	858	594	578

thick at the ground level. In both these types in dry habitats, and also where there is constant trampling, perfectly procumbent types are often found. Cultivation studies reveal that this habit is more often only an environmental modification.

The obtriangular type has larger (2.5-4.4 cm) and thicker (330μ) leaves than the obovate type (2×1 cm×200μ). The apex in the former is round or flat or depressed, while in the latter it is generally more or less flat or slightly depressed. In all the three types, leaves are entire and glabrous and lack stipular appendages. They are arranged either in an opposite or in a subopposite manner, but are clustered at the ends of the branches. Petiole is very short, being about 1 mm (may be up to 3 mm) long. The colour of leaves in obtriangular and

narrowly-obovate types is bright green, while in obovate type it is often purplish or reddish-green.

The flowers arise in terminal sessile clusters in all the three types. They are larger in obtriangular type, in comparison to the other two. There are two boat-shaped and acute sepals, which are persistent in all the three types. Petals are yellow in colour and notched in obtriangular and obovate types. In the former the notch is deeper than in the latter. However, narrowly-obovate type has shallowly notched petals. A distinct mucro is always present in the obovate type, but it is often lacking or is rather indistinct in the obtriangular and narrowly-obovate types (Figs. 6-8). Style is 5-fid in all the three types. Pollen is similar, but differs in size and stainability.

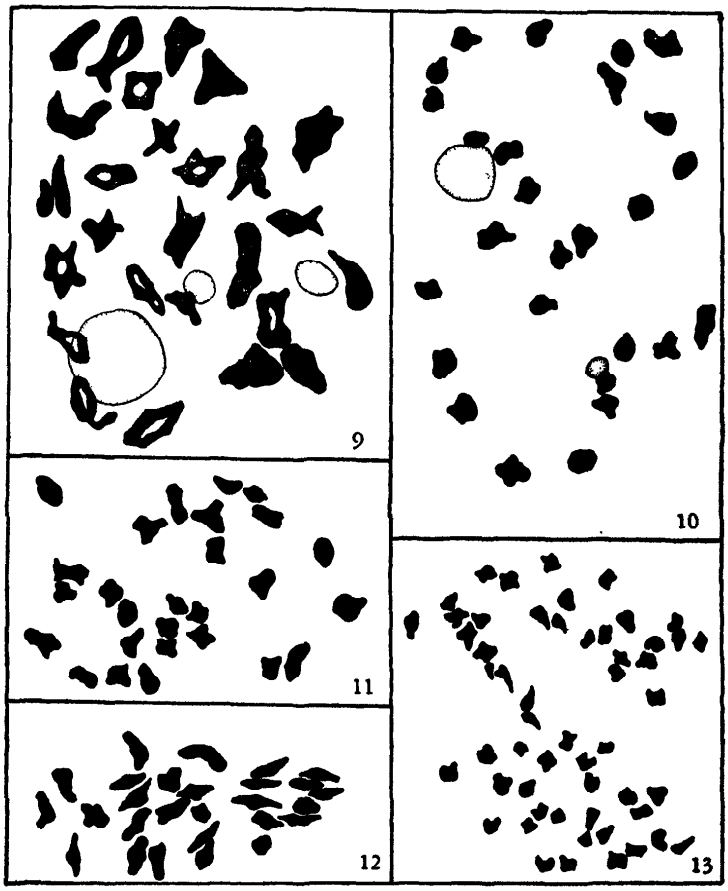


Figs. 6-8. Petal apices in *P. oleracea* : Obtriangular, obovate and narrowly-obovate types respectively.

Fruit is a capsule with transverse dehiscence, containing dark-brown seeds which are tubercled-punctate. The obtriangular type has fewer but larger seeds in a capsule, next comes the obovate type, followed by narrowly-obovate type. However, the percentage of good seed is rather lower in obtriangular type than in the other two types.

Meiosis: The course of meiosis is similar in all the three types. At diakinesis there are 27 bivalents (Figs. 9-10), with no marked size differences. In some preparations about 4-6 bivalents appear to be somewhat smaller than others. Often 2-3 nucleoli were found, and usually one of these was much larger. Upto 5 bivalents were seen attached with nucleoli. The number of chiasmata per bivalent varies from 1 to 3.

At metaphase I, 27 bivalents congress normally and at this stage no significant size differences are noticeable (Figs. 11-12). This stage usually leads to normal anaphase I. However, at times in the obtriangular type one bivalent may disjunct a little late (Fig. 13). Subsequent stages are usually normal and lead to the formation of tetrads at telophase II. As indicated earlier, the percentage of stainable pollen and well filled seeds is somewhat lower in cultivated obtriangular type than in the other two (Table I).



Figs. 9-13. *P. oleracea* (n=27)
Diakinesis (9-10), metaphase I (11-12) and anaphase I (13) ×1300.

Portulaca quadrifida Linn.

This species is chiefly distributed in the tropics of Africa and Asia. In India it grows from 270-1200 m in the Deccan Peninsula and extends to the foot of the Himalayas and sometimes even grows at an altitude of about 900-1200 m.

In the Punjab Plains it grows chiefly in summer months as a weed in fields or their borders and also in dry habitats. The size and general look of the plant is highly modified in relation to the habitats it occupies. In dry habitats, the plants are short and stunted, and the stipular hair become long and shaggy. Numerous morphologically distinguishable collections, on cultivation under uniform conditions, revealed clearly that most of these were merely modifications. However, here and there some collections were encountered which showed marked gigantism when cultivated under uniform conditions. Such collections were investigated separately and the two types differ cytologically. The smaller type is hexaploid, while the gigas one is dodecaploid (Fig. 5).

Both the types conform to the usual description given in various floras (Hooker, 1872 ; Kashyap and Joshi, 1936) in that they are prostrate, slender and profusely branched. Branches root at nodes during rainy season.

Morphology: Stem is about 0.1 cm thick in hexaploid, while it is about 0.15 cm in dodecaploid. The length of internodes is variable and is not significantly different in the two cases.

Leaves are ovate or ovato-oblong, opposite, with a minute petiole. In 12x they are broader (0.4 cm) and thicker (1188μ) than those in 6x (0.3 cm, 924μ). Stomata are larger in 12x (39.5 × 28μ), than in 6x (31.5 × 17.5μ). Stipular appendages are in the form of prominent white hair. The individual hair is about 0.3 cm long in 6x and about 0.4 cm in 12x.

Flowers are solitary and terminal, the calyx tube being half immersed in the extremity of the axis and is surrounded by leaves and long silky hair. Individual flowers are about 0.4 cm long and about 0.7 cm in diameter in 6x, but those of 12x are larger in which the corresponding measurements are 0.68 × 1 cm. All flower parts are larger in the 12x than in 6x.

Pollen is larger in 12x (105μ) than in the 6x (70μ). Stainable percentage of pollen is higher in 6x (80%) than in 12x (50%).

There are 13-16 brown and minutely tubercled seeds per fruit in 6x, while only 8-12 in 12x. Coupled with this reduction in number, is the increase in the size of seeds in 12x. Morphological characters are presented in Table II.

TABLE II

Characters of *P. quadrifida* complex

Characters	Hexaploid	Dodecaploid
Average length of internode (cm)	1-3	1-3.5
Length of nodal hair (cm)	0.3	0.4
Length of leaf (cm)	0.7	0·8
Breadth of leaf (cm)	0.3	0.4
Thickness of leaf (μ)	924	1188
Stomatal size (μ)	31.5 × 17.5	39.5 × 28.0
Length of the flower (cm)	0.4	0.6
Diameter of the flower (cm)	0.7	1.0
Length of the sepal (cm)	0.2	0.35
Breadth of the sepal (cm)	0.15	0.4
Length of the petal (cm)	0.35	0.5
Breadth of the petal (cm)	0.20	0.35
Length of the stamens (cm)	0.3	0.4
Pollen size (μ)	70	105
Pollen fertility (%)	80	50
Number of seeds in a capsule	13-16	8-12
Size of seed (μ)	937.5 × 825	1050 × 975
Seed fertility (%)	93-100	60-90

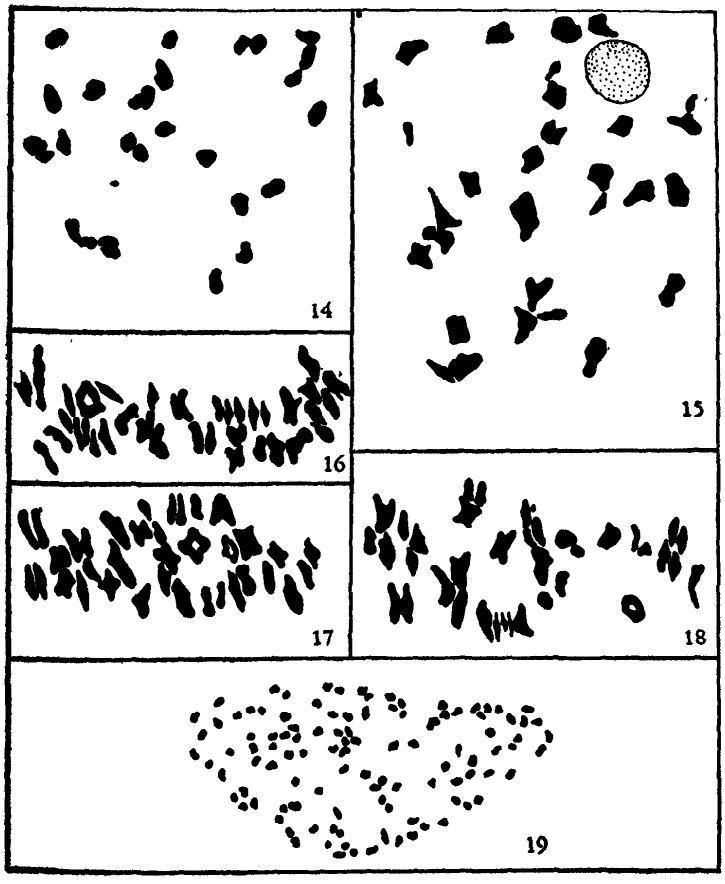
Meiosis—Hexaploid: Pollen mother-cells are about 58μ in diameter and possess 27 bivalents at metaphase I (Fig. 14). The bivalents are rather small, but nearly uniform in size. No multivalent configurations were observed in this type. The subsequent course of meiosis appears to be regular and apparently normal tetrads were always found. The percentages of good pollen and seeds are 80 and 93-100 respectively.

Dodecaploid: The diameter of pollen mother-cells is about 99μ. One cell observed at diakinesis contained $24_{IV}+6_{II}$ (Fig. 15) accompanied by one large nucleolus. Good and well-spread preparation of

metaphase I could only be obtained with great difficulty. Only three such preparations were reliable and the nature of the chromosome associations in them has been tabulated below:

Associations	Combination observed		Total No.	Average No.
Quadrivalents ...	19	18	14	51	17
Bivalents ...	16	18	26	60	20
No. of cells ...	1	1	1	3	—
Text figure nos. ...	16	17,18	—	—	—

If the nature of meiosis in the 4 cells (one at diakinesis and three at metaphase I), is an index of the nature of chromosome associations in this race, then on an average there are $17_{VI}+2o_{II}$ at metaphase I. At any rate the course of meiosis is conspicuous by the presence of quadrivalent associations. This is in strong contrast to the 6x form. Furthermore, there is a reduction in quadrivalent frequency from diakinesis to metaphase I. This is perhaps due to the increase in the terminalization during which process quadrivalents are likely to dissociate into bivalents, resulting in the increase in the number of bivalents. Subsequent stages could not be followed critically, but were apparently normal, and result in tetrads. However, there is reduction in pollen fertility (50%) in comparison to the 6x form. This is also true of the percentage of good seeds, which is 60-90.



Figs. 14-19. *P. quadrifida*
14. Hexaploid (n=27). 15-18. Dodecaploid showing $24_{IV}+6_{II}$, $19_{IV}+16_{II}$ and $18_{IV}+18_{II}$ (17-18), respectively. 19. Root-tip mitosis in Dodecaploid(2n=108) ×1300.

Somatic number: In view of the high chromosome number and multivalent associations it was thought worthwhile to check the number from root-tip preparations. These revealed clearly 108 chromosomes (Fig. 19), which are too small for working out karyotypic details.

DISCUSSION

This study reveals that *Portulaca oleracea* exists as hexaploid at a number of localities in the Punjab, Delhi, Ajmer, Calcutta and Gauhati. The same is also true of the single collection received from Sacavem (Portugal). Even though the species is homoploid, yet three morphologically distinct types have been recognised. Two of these are wild (obovate and narrowly-obovate) and often grow intermixed in cultivated fields and gardens. Outside such habitats, the obovate type appears to be at an advantage and grows in a variety of habitats. It is able to do so because of its weedy tendencies, for example, capacity for induction of wide range of modifications in vegetative and reproductive characteristics, fairly high reproductive capacity, and small seeds, which can ripen even when the plants are uprooted. Furthermore, self-pollination and tendencies for cleistogamy under very adverse conditions are added advantages. It is, therefore, quite understandable that all these characteristics have been responsible for its wide geographic distribution. Outside the tropics, its distribution has also been aided to a great extent by human agency, because it appears to have been one of the early vegetables and its seeds are likely to have been carried by early explorers to all parts of the world (Ridley, 1930).

The cultivated or the obtriangular type has been seldom found to grow wild, in fact, it never does well in open competition, where obovate and, to some extent, also the narrowly-obovate types are at an advantage. The cultivated type is robust and erect, and shows gigantism in almost all the characters when compared with the other two. Even pollen grains and epidermal cells are larger in cultivated type in comparison to the other two types. Since all the three types have the same chromosome number, the gigantism of the cultivated type

is solely at the genic plane, unlike the dodecaploid race of *P. quadrifida*, in which case it is due to polyploidy *per se*.

It may be pointed out that the obovate type appears to be the wild progenitor from which the cultivated obtriangular type has arisen, as the result of the human selection for larger size. In this connection it may be remembered that purslane "was very early known as a vegetable in Europe, being mentioned by Pliny, and for a great many centuries was highly valued as a drug and a potherb" and as salad (Ridley, 1930, p. 635). It is still cultivated in tropical countries. In India it is used as vegetable and its seeds are used in indigenous system of medicine (Kirtikar and Basu, 1933, pp. 240-246).

Previously the species has been known to occur as 2x, 5x and 6x (Table III). Out of these, hexaploid form is by far the most common. The origin of this type is not vivid. However, on the morphological basis (Hagerup, 1932, Fig. 28) it looks reasonably certain that the diploid discovered by Hagerup, near Sahara could conveniently be one of the parents of the hexaploid race. Here it is of interest to note that the species is in all probability a native of Northern Africa and its subsucculent habit is indicative of its being a desert or desert-border plant (Ridley, 1930). Therefore, it may be suggested that one should look for the origin of the wild hexaploid form in this region. The only other work on the African populations of the species is by Stino and El-Shehedi

TABLE III

Chromosome numbers in *P. oleracea* and *P. quadrifida*

Locality	Chromosome number	Association at metaphase I	Authority
	P. oleracea		
Timbuktu	n=9	Bivalents	Hagerup, 1932
,,	n=27	Bivalents	,, ,,
Wisconsin	n=27	?	Cooper, 1935
Wisconsin and Blandy Experimental Farm, Boyce, U.S.A.	2n=54	?	Cooper, 1940 Steiner, 1944
Egypt (wild and cultivated types)	2n=54	Univalents, bivalents and multivalents	Stino and El-Shehedi, 1952
Calcutta	2n=45	?	Sharma and Bhattacharya, 1956
Amritsar, Delhi, Ajmer, Gauhati, Calcutta, Sacavem	2n=54 n=27	Bivalents	Authors
	P. quadrifida		
South India (?)	2n=48	?	Raghavan and Srinivasan, 1941
Calcutta	2n=36	?	Sharma and Bhattacharya, 1956
Amritsar	n=27	Bivalents	Authors
,,	2n=108 n=54	Quadrivalents and bivalents	,,

(1952), who found the Egyptian plants to be hexaploid, but with multivalents at meiosis. It may be recalled that so far multivalents have not been found in this species from any other place (see Table III). It probably indicates that in North Africa this species is still in an unstabilized condition, and that only cytologically balanced (i.e. perfectly diploidized) forms have migrated from their original home.

The discovery of the pentaploid number in root-tips by Sharma and Bhattacharya (1956) is a significant point. The very nature of ploidy reveals that it is of a hybrid origin. However, no data are available about the incidence of such plants, their nature of meiosis, mode of reproduction and perpetuation. The analysis of the karyotype given by the above authors does not afford any clue about its probable origin. Apparently it may indicate

the presence of tetraploid and hexaploid forms in Calcutta region, but we failed to discover either 5x or 4x forms from a large number of samples (including the one very kindly sent by these authors) studied from this region.

In general, only the obovate and the narrowly-obovate types grow together as weeds in cultivated fields and gardens. Otherwise, all the three forms seldom, if ever, grow intermixed. Natural hybridization between former two types does not appear to be common, but the intermediate plants between these are quite fertile. It may be concluded, that on the whole the three types are well isolated, chiefly because of the self-pollination and habitat preferences.

It may be appropriate to give the three types individual varietal rank (within the polytypic species, *P. oleracea* Linn.), because all these are well recognizable and well isolated. The cultivated type has been treated by Thiselton-Dyer (Hooker, 1872) as var. *erecta.* Bailey (1949) treats it as var. *sativa* DC. while Stewart (1869) treated it as a full-fledged species *P. sativa* Haw. Similarly the other two wild types also need to be elevated to varietal ranks.

Sharma and Bhattacharya (1956) reported 2n=36 in *P. quadrifida* Linn. The analysis of the karyotype reported by them clearly reveals that the basi-karyotype is composed of 9 chromosomes, which is one of the common basic numbers of the genus. The two races discovered from Amritsar area are also based on x=9 and, as pointed out earlier, are hexaploid and dodecaploid in constitution. The number 2n=48 discovered by Raghavan and Srinivasan (1941) does not fall in line with the above statement. These workers have reported the number from sectioned material, which may not be entirely reliable in a genus like *Portulaca,* particularly when routine type of fixatives are used. Their report will not be considered further.

The morphological relationships of the tetraploid discovered by Sharma and Bhattacharya (2n=36) have not been worked out so far. However, a comparison of the 6x and 12x forms of Amritsar reveals no qualitative difference whatsoever. The 12x form is gigas in almost all characteristics. It appears to be an autoploid of the 6x type. This is supported by the nature of its meiosis, which is characterized by the occurrence of quadrivalents, that are conspicuous by their absence in the 6x form. The latter characteristic may in fact point to the 6x form being alloploid in constitution. If we treat it as an allohexaploid, then the 12x form is auto-allo-dodecaploid. This conclusion is tentative, pending raising of a colchicine autoploid of the 6x form.

The exact manner of the origin of the 12x is yet to be determined. However, one strong point for its possible mode of origin may now be considered. The 6x form is common and grows in summer months. It flowers during peak summer season after about 11.30 A.M. Often stray "out of season" plants of this race persist even in winter when flowers open very seldom, if ever. This is because of the low atmospheric temperature. A study of such cleistogamous flowers reveals that the pollen grains are variable in size. Some of these are unreduced and approach the size of the pollen grains of the 12x form. The cause of this abnormality is the low temperature (at times touching 0°C) to which the species is not ordinarily adapted. If similar abnormalities occur during embryo-sac formation, then in these cleistogamous flowers, there is a distinct possibility of production of the seeds with double the parental number, i.e. 12x. Such plants would be autoploid of 6x. Before validity of these statements is accepted, two experiments will have to be performed. Firstly, seeds of cleistogamous flowers of the "out-of-season" plants should yield 12x individuals. Secondly, colchicine autoploids of the 6x race should be raised. These should be almost exactly like the 12x race.

The comparative rarity of the 12x plants is in all probability due to their autoploid character. May be the 12x individuals are not good competitors. Nevertheless, they are being maintained in the populations, though in low numbers. Reasons for this have to be looked for in the profuse vegetative growth that takes place during the summer months. Older portions die and lose connection with parental stock. The capacity of rooting at nodes, makes this process virtually equal to vegetative reproduction in its ultimate result. One plant is, so to say, divided into several clones. This could be the possible mode of the preservation of the 12x individuals. Also because of these characteristics, there is no need for selection for the elimination of quadrivalents and consequent increase in fertility.

The species is a pantropical weed and considering its wide geographical distribution, cytological picture obtained thus far (Table III), though very sketchy, is, nevertheless, very significant. It reveals that the species as a whole is polytypic.

Chiefly because of the lack of qualitative differences, taxonomically the two forms do not merit separation even as two varieties. However, some significant pointers exist in the old Indian taxonomic works on this taxon.

According to Roxburgh (1874) *P. meridiana* Linn. is distinct from *P. quadrifida* Linn. He considers the former to be more widespread and the latter "a much rarer plant." Furthermore, the description of former fits more or less with the 6x form, and that of the latter with 12x. The differences between the two species are in number of stamens, styles and time of flowering. These, of course, are rather minor in character. It has yet to be ascertained if the two races discussed here are the same as the two species of Roxburgh (1874). Furthermore, all synonymy and also species like *P. geniculata* Royle (Royle, 1839) have to be critically evaluated taxonomically. It is of interest to mention that Royle collected this species from a fort in Toghulkabad (near Delhi), but he later considered it only a variety of *P. quadrifida* Linn.

In conclusion it may be remarked that *P. oleracea* and *P. quadrifida* are fresh additions to the list of Linnean species, which on critical investigation have been found to be polytypic. Furthermore, in Punjab, all variation in *P. oleracea* though at homoploid level, is nevertheless greater in a qualitative sense, than is found in *P. quadrifida*, even though in the latter species polyploidy has been involved.

SUMMARY

Three distinct and true breeding morphological types have been recognised in *Portulaca oleracea* Linn. These have been referred to as obtriangular, obovate and narrowly-obovate types. The obtriangular type is cultivated and has large leaves. The obovate type is wild with small often reddish-green leaves. The narrowly-obovate type is also wild. Twenty-seven bivalents have been persistently counted in the squash preparations of the pollen mother-cells in all the three types. They are hexaploid, based on x=9.

The species is a native of North Africa, where besides hexaploid, a diploid race has also been discovered. The origin of the 6x race has to be looked for in this region. Furthermore, in view of the multivalent pairing in the Egyptian hexaploids, it appears that only properly balanced and perfectly diploidized types have migrated from the place of their origin.

The obovate type has several weedy characteristics and is, as such, very widely distributed. The cultivated obtriangular type has in all probability arisen from it by human selection for larger size. Since the chromosome number in both is the same, gigantism of the cultivated type is chiefly due to genic causes.

Taxonomically the three types should be included within the same species, but need to be elevated to individual varietal ranks because of their being distinct morphologically.

In *P. quadrifida* Linn. two distinct races have been discovered from Amritsar. One is hexaploid with n=27, and the other is dodecaploid with n=54. The former organises exclusively bivalents, while the latter possesses bivalents and quadrivalents.

A comparison of the hexaploid with the dodecaploid reveals that the latter is gigas in almost all the characteristics. In view of this and also the quadrivalent formation in dodecaploid, it is suggested that the 12x race is an auto-allo-dodecaploid.

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