Annals of Arid Zone 61(1): 53-59, 2022

Evaluation of Parthenocarpic Cucumber (*Cucumis sativus* L.) Cultivars for Summer Cultivation under Insect-Proof Net House in Indian Hot Arid Region

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Received: January 2022

Abstract: Protected cultivation of cucumber (*Cucumis sativus* L.) is gaining ground on a commercial scale in arid-western parts of India. The summer cultivation of cucumber is highly remunerative due to high market price. In the present investigation, eight commercial parthenocarpic cucumber cultivars were evaluated for growth, yield and quality traits under insect-proof net house condition in arid region of Rajasthan during 2017. Results revealed that the significantly higher vine length (332.00 cm) and stem diameter (0.53 cm) was observed in hybrid 'Ruchi-707', whereas the maximum leaf area (418.00 cm^2) was noted in 'Aviva'. Hybrid 'Aviva' took minimum number of days to flowering (29.00 days) and first fruit set (32.40 days), while 'Ruchi 707' was observed earliest in first fruit maturity (38.3 days) as well as longest in crop duration (97.3 days). Hybrid 'Aviva' was also recorded the highest number of flowers $vine^{-1}$ (38.5), fruit volume (360 cm^3), fruit weight (228.00 g), TSS (5.73°Brix) and ascorbic acid content (3.58 mg $100g^{-1}$ FW). However, 'Ruchi-707' was observed with the highest number of fruits per vine (16.5), fruit yield per vine (3.74 kg) and fruit yield per 500 m^2 (11.57 t) and longest shelf-life (5.5 days). The fruit yield per vine had a significant positive correlation with average fruit weight (r= 0.891**), and crop duration (r=0.893**) and significant negative correlation with the number of fruits per vine (r= -0.844**). Hybrid 'Ruchi 707' also fetched the highest net returns (Rs. 2,45,642) and B:C ratio (5.62) per 500 m^2 . Based on earliness, fruit yield and commercial quality, hybrid 'Ruchi 707' followed by 'Aviva' were found suitable for summer production in the arid region of Rajasthan.

Key words: Arid, insect-proof net house, parthenocarpic cucumber, net returns, yield.

Cucumber (*Cucumis sativus* L.) is an important salad crop in India. Cucumber is a thermophilic crop cultivated in open fields during the spring-summer period and performs well in a temperature range of 25 to 29°C. In Rajasthan, cucumber is emerging as a remunerative crop being grown on around 850 ha of area (Anonymous, 209). However, in hot-arid climatic conditions of Rajasthan, the prevalence of high temperature during summer and biotic stresses in open conditions make it difficult to get desired level of productivity and good quality produce. The unavailability of adapted cultivars, costly seeds and the high diseases-pest incidence with the associated cost of plant protection measures are the other reasons for low productivity and less profitability of cucumber in open field cultivation. Hence, nowadays many farmers in western Rajasthan are growing cucumber under protected conditions on a commercial scale. For widespread adoption of greenhouse technology various innovation are taking place in resource limiting environment of western Rajasthan (Khapte *et al*., 2021). The protected vegetable cultivation technologies are highly suitable and potentially remunerative particularly for the water-scarce and harsh climatic conditions like western Rajasthan. In protected cultivation, an insect-proof net house can be feasibly adopted by creating a physical barrier to check the entry of insect pests and vectors (Sabir and Singh, 2013) can help produce quality vegetables with higher returns and reduced pesticide residues (Wani *et al*., 2011).

Cucumber is commonly a monoecious annual having almost all sex forms. However, the monoecious varieties or hybrids are not suitable for protected cultivation due to pollination and other factors. Therefore, under the protected structures, like insect-proof net house conditions, parthenocarpic varieties of cucumber are preferebly grown for higher fruit yield with quality fruits. Since a high investment is involved in terms

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of erecting protected structures, scarce water and high seed cost, selection of a suitable parthenocarpic cultivar is a pre-requisite for remunerative crop production under protected conditions (Kumar *et al*., 2019a). Moreover, the commercial-quality traits of a cultivar to be remunerative depends upon yield potential, earliness and quality characters for taste, flavor and shelf-life. Therefore, a promising cultivar for specific agro-ecosystem should have a good compromise between fresh yield, earliness and quality traits to satisfy the demands of the local market for fetching higher returns (Kumar *et al*., 2019b). As the parthenocarpic cucumber is a relatively new to western Rajasthan, therefore the present study was conducted to identify the suitable parthenocarpic cucumber cultivars in terms of yield, quality and economics for summer cultivation under insect-proof net house conditions of western arid plains of India.

Materials and Methods

The experiment was carried out at College of Agriculture, Jodhpur (26°15′N latitude and 72°59′E longitude; 231 MSL) during summer (February to June) 2017 in 500 m^2 insect-proof net house: side wall covered with 40 mesh insect proof net and roof was covered with UV stabilized monofilament net. Eight parthenocarpic cucumber cultivars including one open pollinated cultivar Pusa Parthenocarpic Cucumber 6 (PPC 6) and seven F_1 hybrids viz., Aviva, 'Sunstar Rz, Valleystar Rz, WS 557, WS 1019, WS 1018 and Ruchi 707 were evaluated in randomized block design with three replications. The soil of the experimental site was loamy sand and was slightly alkaline (pH 8.2), low in organic carbon (0.13%) and available N (174 kg ha^{-1}), medium in available P (22.2 kg ha^{-1}) and high in available K (325 kg ha^{-1}). The daily mean minimum and maximum temperature and relative humidity of ambient conditions during the crop period were ranged from 15.1-43.5°C and 6-70%, respectively and the daily evaporation exceeds the rainfall (Fig. 1).

The crop was sown at 30 cm spacing in paired rows of 40 cm apart on 80 cm wide raised beds. Each experimental plot consisted of 52 plants. The paired row system of planting was followed to have more aeration and sufficient space between the plants. Plants were trained to single stem vertically with plastic thread over trellis by regular pinching off side shoots. For irrigation drip lines (16 mm) having in-line drippers of 4.0 LPH discharge rate spaced at 30 cm intervals placed 10 cm away from plants. At the time of land preparation, 25 t ha^{-1} compost and 1.0 t ha^{-1} neem cake were mixed by tilling in the top 15 cm soil. The recommended dose of NPK (120:60:160 kg ha^{-1}) was applied in the form of urea, single super phosphate and muriate of potash. The half dose of N and the full dose of P_2O_5 and K_2O were applied as basal at the time of field preparation, while the remaining half dose of

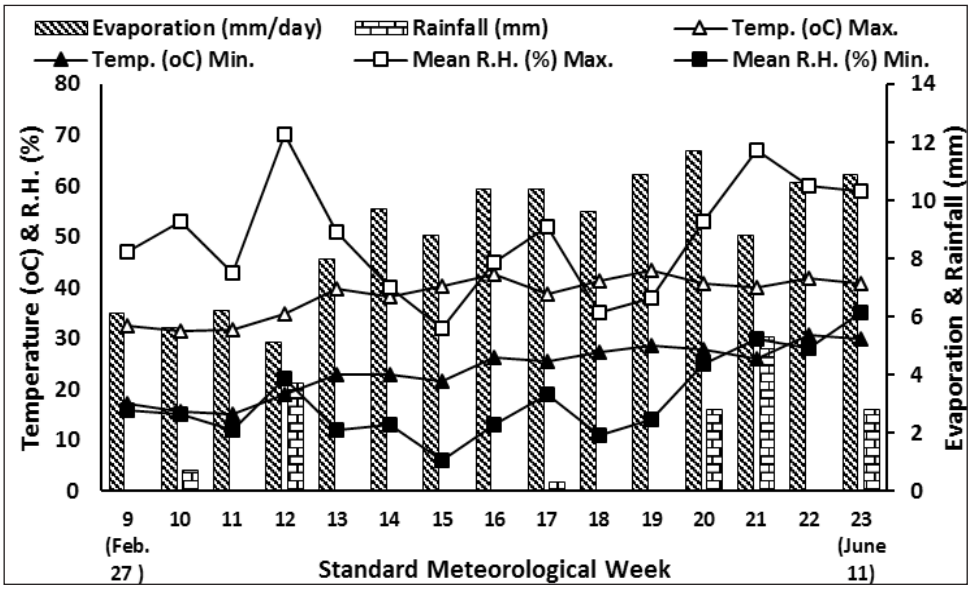

Fig. 1. Weather conditions of the experimental site during the crop duration.

N was applied at 30 days after sowing by side dressing. A combi-fertilizer (N:P:K 19:19:19) at 2 g litre^{-1} of water was also applied at the time of fruit development (40 days after sowing) and at weekly intervals through fertigation. Necessary plant protection measures as per the recommended package of practices were applied to protect the crop from pests and diseases.

Observations on growth parameters like vine length, intermodal length, leaf area and stem diameter, and developmental parameters like days to first flower appearance, days to first fruit set, days to first fruit harvest and crop duration, number of flowers per vine and fruit set percentage were measured on five randomly selected plants from each plot in each replication. Measurement of leaf size (length and width) was taken during peak bearing as per methods suggested by Rouphael *et al*. (2010). Fruit parameters and yield attributes such as fruit length, fruit diameter, fruit volume, number of fruits per vine, average fruit weight, fruit yield per vine and total fruit yield were noted from five random fruits from the third harvest. The quality analyses for total soluble solids (TSS), ascorbic acid contentand shelf-life were performed on the selected fruit samples. The ascorbic acid was determined as per standard procedures of AOAC (1990), while TSS (°Brix) were recorded with the help of hand refractometer. Shelf-life of freshly harvested fruits was recorded and loss in fresh weight was recorded based on 15% weight loss at room temperature.

The mean data of all the parameters from each replication were subjected to analysis of variance of randomized block design according to Gomez and Gomez (1984). Association of various characters was worked out by Pearson's simple correlation coefficient and tested for significance.

Results and Discussion

Growth parameters

Parthenocarpic cucumber cultivars varied significantly in terms of vine length, stem diameter, internodal length, and leaf area at final harvest under insect-proof net house conditions (Table 1). The highest vine length and stem diameter i.e., 332 cm and 0.53 cm were recorded in 'Ruchi 707' which was at par with 'Aviva'. The internodal length was found shortest in 'Valleystar Rz' (7.04 cm) and longest internodes were recorded in 'PPC 6' (12.3 cm). Hybrids 'Aviva' (418 cm^2) followed by 'Ruchi 707' (376 cm^2) and 'Sunstar Rz' (374 cm^2) recorded significantly highest leaf area. Jat *et al.* (2014) were also reported similar results in cucumber under greenhouse. The differences in growth parameters in cucumber hybrids could be attributed to their genetic make-up and environmental factors like the diurnal variation in temperatures (Xiong *et al.,* 2002).

Development parameters

As evident from Fig. 2, parthenocarpic cucumber hybrids had significant variations in various development characteristics from first flower appearance to total crop duration. The

Table 1. Growth parameters, yield attributes and yield of parthenocarpic cucumber hybrids in insect-proof net house

Variety	Vine length (cm)	Inter-nodal length (cm)	Stem dia-meter (cm)	Leaf area (cm^2)	No. of flower vine^{-1}	Fruit set (%)	Fruit length (cm)	Fruit dia-meter (cm)	Fruit vol. (cm^3)	No. of fruits vine^{-1}	Avg. fruit weight (g)	Fruit yield (kg vine^{-1})	Fruit yield (t 500 m^{-2})
PPC 6	179	12.3	0.46	296	26.4	54.2	16.8	3.53	160	14.2	147	2.10	6.49
Aviva	329	9.7	0.49	418	38.5	37.6	22.9	4.50	360	14.5	228	3.30	10.21
Sunstar Rz	201	7.3	0.44	374	28.7	51.8	18.3	4.37	270	14.8	166	2.46	7.61
Valleystar Rz	234	7.0	0.47	222	26.2	67.6	18.8	3.80	211	17.8	170	3.05	9.43
WS 557	142	7.1	0.49	188	22.9	48.5	22.2	4.20	301	11.3	152	1.73	5.35
WS1019	251	7.6	0.50	236	26.6	54.0	21.0	3.37	188	14.6	155	2.31	7.14
WS 1018	219	7.2	0.42	214	25.0	62.5	19.0	3.63	190	15.8	152	2.40	7.42
Ruchi 707	332	8.5	0.53	376	31.8	51.7	22.0	4.20	301	16.5	226	3.74	11.57
SEm (±)	5.4	0.43	0.014	8.83	1.31	2.11	0.98	0.158	8.7	0.68	4.4	0.113	0.459
CD (P=0.05)	16.5	1.29	0.041	26.8	3.98	6.41	2.98	0.479	26.4	2.05	13	0.34	1.12

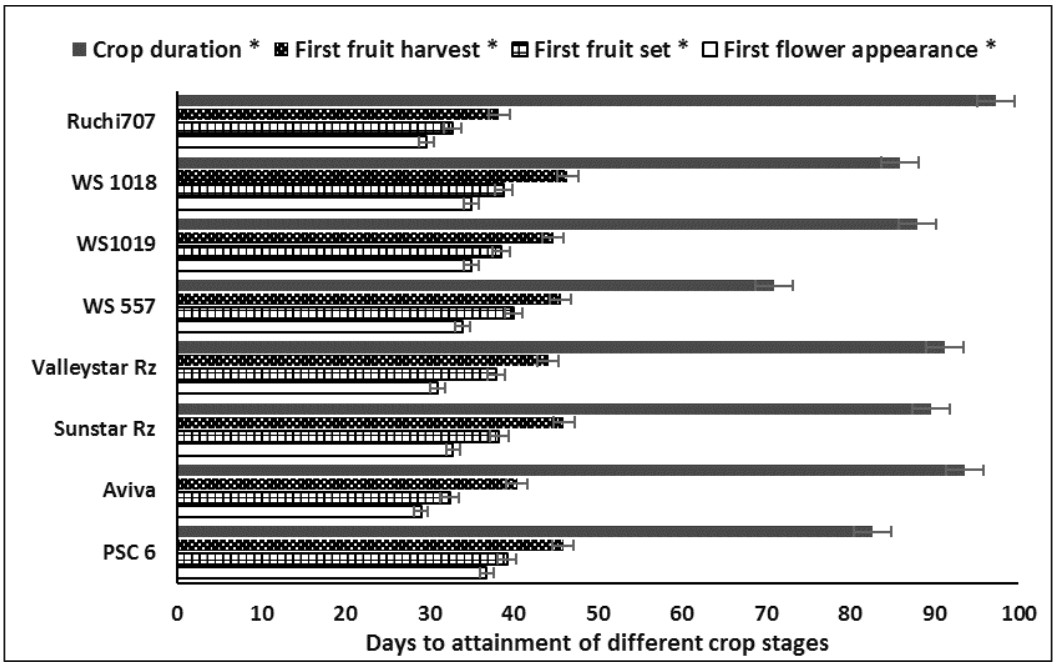

*Fig. 2. Days to attainment of different crop stages in parthenocarpic cucumber hybrids in the insect-proof net house (*significant at 5% level of significance).*

days taken to first flower appearance and first fruit set are desirable characters, as the early harvest of fruits in a cultivar fetches higher market price and ensures higher cropping intensity in a protected structure. Being at par with 'Ruchi 707', hybrid 'Aviva' was found to be earliest in flower appearance (29.0 days), fruit set (32.4 days) and fruit harvesting (40.4 days), while 'PPC 6' and 'WS 1018' were observed to take the longest duration from first flower appearance to fruit harvest. The longest and shortest crop durations were recorded in 'Ruchi 707' (97.3 days) and 'WS 557' (71.0 days), respectively. These findings are following the reports of Bisht *et al.* (2011) in cucumber under naturally ventilated polyhouse. Earliness in cucumber was viewed due to genetic character by Kumar *et al*. (2008) while Ene *et al.* (2016) reported it to be the effect of the growing environment. The shorter period for first fruit harvesting and longer crop durationpermits the crop to produce more having a longer fruitingperiod and shorter length of the vegetative growth.

Flower and fruit characters

Data (Table 1) indicates that 'Aviva' (38.5), being at par with 'Ruchi 707' (31.8), produced the maximum number of flowers per vine whereas the minimum number of flowers per vine were observed in 'WS 557' (22.9). However, hybrid 'Valleystar Rz' exhibited the highest fruit set (67.6%). The findings are in close conformity with those of Nwofia (2015) in cucumber. The number of flowers per vine and fruit set per cent has an important role in the production potential of a variety and are governed by the environmental factors (Ene *et al.*, 2016). The results (Table 1) further reveals that among the different parthenocarpic cucumber hybrids, 'Aviva' was also observed with significantly higher fruit length (22.9 cm), fruit diameter (4.50 cm) and fruit volume (360 cm^3). These results are supported by the findings of Jat *et al.* (2014).

Yield attributes and yield

Cucumber hybrids differed significantly in terms of yield attributing parameters like the number of fruits per vine, average fruit weight, fruit yield per vine and total fruit yield under insect-proof net house condition (Table 1). Hybrid 'Aviva' recorded the significantly higher average fruit weight (228 g) and the number of flowers $vine^{-1}$ (38.5) but less fruit set (37.6%) as compared to 'Ruchi 707' (51.7%) and 'Vallystar Rz' (67.6%). Similar findings have also been reported by Gruetze *et al*. (2016) in cucumber under-protected cultivations. The highest fruit yield per vine and total fruit yield per 500 m^{-2} (3.74 kg and 11.57 t, respectively) were registered in 'Ruchi

Table 2. Significant correlations between different crop parameters of parthenocarpic cucumber in insect-proof net house

Parameter		Correlations coefficient (r)
Leaf area	Number of flowers vine^{-1}	0.882**
	Average fruit weight	0.760*
Days to first flower appearance	Number of flowers vine^{-1}	-0.737*
	Days to first fruit set	0.820**
	Days to first fruit harvest	0.808*
	Fruit volume	-0.780*
	Average fruit weight	-0.894**
	Fruit yield vine^{-1}	-0.844**
	Average fruit weight	0.886**
	Crop duration	0.713*
	Fruit yield vine^{-1}	0.740*
Number fruits vine^{-1}	Crop duration	0.784*
	Fruit yield vine^{-1}	0.709*
	Fruit volume	-0.780*
	Crop duration	-0.762*
	Fruit yield vine^{-1}	-0.844**
Days to first fruit harvest	Average fruit weight	-0.954**
	Fruit yield vine^{-1}	-0.881**
Fruit set (%)	Fruit volume	-0.733*
Average fruit weight	Fruit volume	0.758*
	Fruit yield vine^{-1}	0.891**
Crop duration	Fruit yield vine^{-1}	0.893**

*Significant at 5% and ** at 1% level of significance.

707' followed by 'Aviva' (3.30 kg vine^{-1} and 10.21 tonnes, respectively) which was found at par with 'Valleystar Rz' (3.05 kg vine^{-1} and 9.43 tonnes). 'Ruchi 707' recorded 13.3 and 22.6% higher total fruit yield over 'Aviva', and 'Valleystar Rz', respectively. These results are in agreement with the findings of Dantas (2011).

The number of fruits per vine is one of the major contributing factors to the yield and the resulted variation for the number of fruits per vine amongst the cucumber hybrids might be due to fruit set percentage, genetic nature and their response to environmental conditions. As compared to 'Ruchi 707', hybrid 'Vallystar Rz' recorded the higher fruit set and more number of fruits pervine but lower average fruit weight. However, 'Ruchi 707' recorded high average fruit weight as compared to 'Valleystar Rz', while more number of fruits per vine as compared to 'Aviva'. 'Ruchi 707', therefore, had the maximum fruit yield vine^{-1} and total fruit yield.

Correlations between growth, development and yield parameters

The significant correlations between crop parameters are presented in Table 2. As the leaf area provides a larger site for photosynthesis for growth and yield, the important yield parameters like the number of flowers per vine (r = 0.882**) and average fruit weight (r = 0.760*) were found significantly positively associated with leaf area. The correlation studies derived from different parameters under investigations reveal that besides the growth parameters, the developmental stages also influenced the yield of the cucumber hybrids. The number of fruits per vine had a significant positive correlation with crop duration (r=0.784*). However, due to short crop duration earliness resulted into significantly negative correlation with the number of flowers per vine (r=-0.737*), average fruit weight (r=-0.894**) and fruit yield per vine (r=-0.844**). This trend was also evident through days to first fruit harvesting which showed a significantly negative correlation with the number of flowers per vine (r=-0.761*) and average fruit weight (r=-0.954**). As the days to first fruit set having a significant positive correlation with first fruit harvest (r=0.930**) had a significant negative correlation with crop duration (r=-0.762*). The crop duration influenced fruit production it showed a significant positive correlation with yield per vine (r=0.896**). These findings are following the results of Thakur *et al*. (2015) in bottle gourd. Significant positive correlation between yield vine^{-1} and total fruit yield with number of flowers per vine (r=0.740* and

Table 3. Fruit quality characteristics of parthenocarpic cucumber hybrids in insect-proof net house

Variety	TSS (°Brix)	Ascorbic acid (mg 100g^{-1} FW)	Shelf-life (days)
PPC 6	4.77	2.81	4.30
Aviva	5.73	3.58	5.20
Sunstar Rz	4.20	2.83	3.27
Valleystar Rz	4.77	2.73	3.40
WS 557	4.07	2.73	3.57
WS 1019	4.52	2.38	2.77
WS 1018	4.27	2.78	2.50
Ruchi 707	5.13	2.98	5.53
SEm (±)	0.210	0.098	0.193
CD (P=0.05)	0.636	0.297	0.585

Table 4. Economics of parthenocarpic cucumber production under insect net proof house (per 500 m²)

Varieties	Variable cost due to seed (Rs.)	*Total cost of cultivation (Rs.)	**Gross returns (Rs.)	Net returns (Rs.)	B: C ratio
PPC 6	3095	43733	162487	118784	2.71
Aviva	3095	43733	255337	211604	4.83
Sunstar Rz	15475	56113	190342	134229	2.39
Valleystar Rz	15475	56113	235993	179880	3.21
WS 557	15475	56113	133850	77736	1.38
WS 1019	15475	56113	178736	122623	2.19
WS 1018	15475	56113	185700	129586	2.31
Ruchi 707	3095	43733	289375	245642	5.62

*Fixed cost Rs. 40,638; **Sale price @ Rs. 25 kg^{-1}

0.739*), average fruit weight (r=0.891** and 0.889**), crop duration (r=0.893** and 0.896**) were noticed. The results are as per the findings of Jat *et al.* (2014) in cucumber. Fruit yield is closely associated with the fruit number and average fruit weight, and in the present study, there was a significant positive correlation (r=891*) was for average fruit weight, while the fruit number per vine showed significant negative correlation (r=844*) with fruit yield per vine, hence the total fruit production. A study from same area has also revealed similar associationship of fruit number and mean fruit weight with fruit yield in vine grown tomatoes under protected condition (Khapte *et al*., 2018).

Quality parameters

Parthenocarpic cucumber hybrids grown under insect-proof net house varied significantly in terms TSS, ascorbic acid and shelf life (Table 3). Quality attributes of cucumber fruit like TSS and ascorbic acid are important toincreases flavour and palatability for *salad*, nutritive value and help in better retention of colour and flavour. The highest values of TSS and ascorbic acid content were recorded in 'Aviva' (5.73 °brix and 3.58 mg 100 g^{-1} FW, respectively) followed by 'Ruchi 707' (5.13 °brix and 2.98 mg 100 g^{-1} FW, respectively). Enhanced deposition of solids in fruit may be the probable reason for higher TSS values. The longest shelf life was noted in 'Ruchi 707' (5.53 days) followed by 'Aviva' (5.20 days) fruits which are ascribed to higher TSS and ascorbic acid content in these hybrids. The results are following the findings of Kurubetta *et al*. (2009).

Economics

The highest net returns and B:C ratio (Rs. 2,45,642 and 5.62, respectively) per 500 m² were recorded in 'Ruchi 707' (Table 4) while the minimum net returns and B:C were recorded in 'WS 557' (Rs. 77,737 and 1.38, respectively). It could be ascribed to low seed cost and higher yields of 'Ruchi 707'. The results are also supported by findings of Pozderec *et al*. (2010) who were also of the view that protected cultivation of cucumber presents a lot of opportunity in term of better economic gain in a shorter span of cropping period.

It can be inferred from the study that hybrid 'Ruchi 707' recorded the highest fruit yield vine^{-1} and total fruit yield, early fruit maturity, longest shelf life, highest net returns and B:C ratio per 500 m² and low seed cost followed by 'Aviva'. Therefore, among the parthenocarpic cucumber cultivars, 'Ruchi 707' and 'Aviva' F_1 hybrids could be economically good options for small and marginal farmers for protected cultivation in western Rajasthan.

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Printed in March 2022