Research Article

Standardization of Seed Production Technology in Radish (*Raphanus sativus*) Cv. Mino using Different Stecklings Size

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Abstract | Quality seed is an important attribute for higher yield and better crop production for famers and is a foundation of any crop species. Root to seed method is widely used in Pakistan for radish seed production but still low and inferior quality seed is being produced that cause a significant loss in yield due to lack of standardization of seed production technology.Therefore, to improve seed yield and quality, present research was conducted toevaluate the effect of steckling size on plant growth and seed yield of radish.Steckling of different lengths (5cm, 10cm, 15cm) and width (4.9cm, 6.3cm, 8cm) along with random size steckling and control treatment (full size steckling) were planted and evaluated for different vegetative and reproductive parameters. Results showed that control (T_1) and random sizesteckling(T_2) improved plant growth by increasingplant height, number of primary branches/plant, number of secondary branches/plant, number of productive stems/plant and number of pods/plant. But still, both treatments significantly delays flowering. In terms of seed yield and quality, longer (T_5=15cm) and wider stecklings (T_6=4.9cm and T_7=6.3cm) increased number of seeds/pod, seed size (mm), seed vigor index and total seed yield/plant(g). However, extra wide stecklings (8cm) significantly reduced all morphological and reproductive growth parameters. Therefore, treatments T_6 and T_7 proved to be better for production of higher seed yield with improved quality.

Received | April 22, 2021; **Accepted** | July 18, 2021; **Published** | August 29, 2021
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Citation | Manzoor, A., M.S. Naveed, S.R. Ali, D. Ibrar, S. Syed, S. Ashraf and R. Ahmed. 2021. Standardization of seed production technology in radish (*Raphanus sativus*) Cv. mino using different stecklings size. *Pakistan Journal of Agricultural Research,* 34(4): 725-731.
DOI | https://dx.doi.org/10.17582/journal.pjar/2021/34.4.725.731
Keywords | Plant growth, Seed quality, Seed vigor, Seed yield, Stecklings

Introduction

Radish (*Raphanus sativus*) is one of the important crops of Cruciferaefamily that is believed to be originated from central or western China and Indo-Pak subcontinent (Haq *et al*., 2012). It is an edible root vegetable that has been used in variety of culinary applications since ancient times and is widely used as staple food in various tropical countries. Although the whole plant is edible but the most common eaten part is fleshy taproot along with tops are used as leafy vegetables (Kiran *et al*., 2016). From medicinal point of view, its consumption produce cooling effect and can used to increase appetite and prevents constipation. Both fleshy root and tender leaves are rich in proteins, minerals, carbohydrates, and vitamins A and C (Haq *et al*., 2012). It is recommended for patients diagnosed with jaundice, enlarge liver and spleen. It is also popular vegetable for kitchen gardening because it's a short duration vegetable crop and is normally ready for consumption between three to six weeks after sowing (Bakhsh *et al*., 2006).

World production of radish is approximately 7 million tons per year that represent 2% of all vegetables production at global level (Husnain *et al*., 2020). Despite its wider adaptability, short duration and minimum crop failure, there is a decrease in radish area in Pakistan from 10133 to 9641 ha in a previous decade (2009-2019) (GOP, 2009, 2019), respectively. Moreover, the average yield of radish in Pakistan is also comparatively low as compared to its potential (Jilani *et al*., 2010).

The main reason for low productivity of radish in Pakistan is unavailability of high quality seed, mostly research has been done on improving crop production, but yet no attention is given in improving seed quality (Ilyas *et al*., 2013). Thus, due to low quality of locally produced radish seed, a large quantity of seed available in market is imported from other countries (Noor *et al*., 2020). Almost 99% of the radish seed is imported on which heavy amount is spent and also there are adaptability issues of imported seeds. In 2013-14, Pakistan imported 130.588 metric ton of radish seed on which 84.3669 million rupees was spent (GOP, 2014). Imported seeds are usually expensive and sometimes not available during radish sowing time. Further, private seed companies are getting benefits from this situation and selling the imported hybrid seed to the farmers at extraordinary higher rates (Malek *et al*., 2012).

Quality of radish seed is not up to the standards due to improper and uncertified seed production technology such as seed sowing, harvesting and postharvest treatments. Seed crop have to be healthy in order to produced good quality seed (Husnain *et al*., 2020). There are usually two methods for seed production in root crops, *in situ* (seed to seed method) and *ex situ* or transplanting (root to seed method). In seed to seed method, roots are allowed to overwinter and produced seeds in spring in the same field without uprooting them. However, it can produce seedsof inferior quality becausethere is no sorting or removal of deformed and forked roots that further leads to mixing of seeds produced from healthy roots with seeds of inferior quality. But in *ex situ* method, prepared roots (steckling) are transplanted immediately in a well prepared field (Tomar *et al*., 2016) whereas; forked, pithed, deformed and misshapen roots are discarded. In both seed production methods, production of edible root remain the same, but handling of these mature roots make a difference (Rajan, 2007). However, in Pakistan, root to seed is a standard method to produce high quality seed because through this technique true to type and healthy roots are selected for replanting as stecklings (Anjum and Amjad, 2002).

In root to seed method, stecklings are commonly selected at a time when vegetative growth is completed and all distinguishable varietal characteristics like shoots and roots are well develop (Kumar *et al*., 2007). It is suggested that roots should be uprooted before flowering and transplanted after proper trimming i.e., in the form of two-inch root cut and one inch of shoot cut or cutting of 1/2-2/3rd of roots and trimming of top also improve seed yield (Hoque *et al*., 2015). Like other factors in radish seed production, steckling size also has an important role in producing good quality and vigorous seed (Noor *et al*., 2020). Long rooted radish has to be trimmed up to 3/4thand for small rooted 1/2th portion have to cut in order to left 12-15 cm of root for replanting. For shoot portion, trim 2/3rd portion and leave small undeveloped central leaves (Rajan, 2013). Steckling of greater size has positive effect on seed yield as compared to smaller ones because large size steckling produced more no of pods/plant, increase seed number/pod, seed weight and average seed yield. It is reported that half and medium root cuts produce higher seed yield with respect to smaller cut roots (Hamid *et al*., 2002).

Usually in Pakistan farmers/growers select large and extra-large roots for steckling preparation according to their perception that large size roots produce more number of seeds. Therefore, the present research was conducted to evaluate the effect of steckling size on yield parameters and seed health (size, weight) of radish with an aim to optimize seed production technology so that regular supply of high quality, locally produced seeds at economical rates should be available to the farmers.

Materials and Methods

Experimental site

The present research was conducted in vegetable research area of Barani Agricultural Research Institute, Chakwal (72° longitude, 32° latitude and 575m altitude) during 2019-20 with an objective to find out best steckling size for high quality seed production.

Plant material and treatments

Seeds of radish cv Mino were sown on flat beds at 5 cm plant to plant and 75 cm row to row distance in mid-October. After 10 weeks, mature true to type roots were harvested and desired root cuts to prepared stecklings were acquired. Except control treatment (T_1= full size steckling/no root cut), steckling of random size (T_2) along with steckling of different length (T_3= 5cm, T_4= 10cm, T_5= 15 cm) and width (T_6= 4.6 cm, T_7= 6.3 cm, T_8= 8.0cm) were replanted in flat beds with recommended distance and cultural practices. The experiment was conducted in randomized complete block design (RCBD) with three replications of each treatment.

Data collection

Data of different vegetative and reproductive growth parameters i.e. days to flowering, plant height (cm), number of leaves/plant, number of primary branches/plant, number of secondary branches/plant, number of productive stems/plant, number of pods/plants and pod length (cm) were recorded.

Seed yield and quality parameters

Seed yield and quality were assessed by number of seeds/pod, total seed yield/plant (g), seed size (mm) and seed vigor index. Seed vigor index in calculated by following formula (Jyoti *et al.*, 2016).

Seed vigor index= Germination (%) × Total seedling length (cm)

Statistical analysis

The collected data were further subjected for analysis of variance (ANOVA), least significance difference (LSD) and correlation coefficient by R package software (Version 1.2.1335).

Results and Discussion

Morphological variability

In present research, results for analysis of variance (ANOVA) showed significant variability for morphological (vegetative and reproductive) traits among different treatments at 5% level of significance (Table 1). According to the results, minimum days to flowering taken by different size of steckling were 37.33, while maximum days to flowering were 67.33 days. Plant height parameter had considerable variation as shorter plants were at 48.96 cm height whereas higher plants reached to 156.33 cm height. Number of leaves/plant was ranged from 10.00 to 37.33. For primary branches, minimum branches were 5.66 and maximum were 23.33. Secondary branches were also varied in number that was ranged 6.66 to 17.00 branches per plant. In terms of reproductive growth, number of productive stems/plant was ranged from 7.00 to 23.00. Significant variation was observed for number of pods per plant that varied from 182.33 to 552.00 pods per plant. Similarly pod length remained between 3.70 cm to 7.20 cm. Seed yield parameters like number of seeds/pod varied from 4.33 to 8.66, total seed yield/plant showed minimum 10.26 g and maximum 18.26 g weight. Seed of different vigor were studied (292.27-845.00) while for seed size, smaller seeds were of size 0.14 mm and larger seeds had 0.45 mm size.

Table 1: *Mean square for different morphological traits, grand mean, range and coefficient of variation (CV%) among different steckling sizes.*

Traits	MSg	Grand Mean	Range	CV%
Days to flowering	199.143	48.00	37.33 – 67.33	5.85
Plant height	3765.98	84.58	48.96 – 156.33	5.43
Number of leaves	279.99	25.46	10.00 – 37.33	8.95
Number of primary branches	118.37	15.54	5.66 – 23.33	9.14
Number of secondary branches	62.26	11.08	6.66 – 17.00	15.19
Number of productive stems	75.75	13.375	7.00 – 23.00	13.60
Number of pods/plant	47175.9	340.71	182.33 – 552.00	2.55
Pod length	3.56	4.98	3.70 – 7.20	7.43
Number of seeds/pod	6.28	6.50	4.33 – 8.66	11.45
Total seed yield/plant	21.37	14.22	10.26 – 18.26	5.92
Seed vigor	124136	549.64	292.27 – 845.00	26.45
Seed size	0.034	0.26	0.14 – 0.45	15.36

MSg: Mean square due to genotypes; CV: Coefficient of variation.

Table 2: *Effect of different different steckling size on morphological traits of radish cv. Mino.*

Treatments	Parameters							
	DF	PH (cm)	NL	PB	SB	Prst	Pods	PL (cm)
T_1	63.3 ± 2.60 a	156.3 ± 3.84a	37.3 ± 1.45a	23.3 ± 0.88 a	17.0 ± 1.15a	23.0 ± 1.59a	552.0 ± 10.23 a	5.7± 0.26 b
T_2	55.3 ± 1.76 b	110.4 ± 4.41b	32.6 ± 2.33b	7.6 ± 0.33 d	6.6 ± 0.88d	11.3 ± 1.45cd	465.3 ± 7.22 b	4.3 ± 0.12d
T_3	44.0 ± 1.15de	54.5 ± 0.98e	10.0 ± 1.15e	14.3 ± 0.67c	9.6 ± 0.88 bc	8.6 ± 0.88de	322.0 ± 3.60e	4.8 ± 0.20cd
T_4	45.0 ± 0.57cde	91.5 ± 1.53c	18.6 ± 0.88d	16.0 ± 1.15c	7.0 ± 1.15cd	11.3 ± 0.33 cd	329.3 ± 1.76 de	4.2 ± 0.27 dc
T_5	37.3 ± 1.45f	66.53 ± 2.59d	33.3 ± 0.88b	5.6 ± 0.33d	18.6 ± 1.20 a	7.0 ± 0.57 e	182.3 ± 2.03 f	7.2 ± 0.21a
T_6	42.0 ± 1.15ef	84.43 ± 2.62c	16.0 ± 0.58d	22.0 ± 1.15a	7.3 ± 0.33 cd	15.3 ± 1.45 b	350.3 ± 2.03c	3.7 ± 0.15 e
T_7	48.0 ± 1.15cd	63.96 ± 2.77d	25.3 ± 0.88c	19.0 ± 0.57b	10.6 ± 0.33 b	14.0 ± 1.15 bc	185.0 ± 2.08f	4.5 ± 0.18 d
T_8	49.0 ±1.53 c	48.96 ± 1.16e	30.3 ± 0.88b	16.3 ± 0.88c	11.6 ± 1.45 b	16.3 ± 0.88 b	339.3 ± 1.45 cd	5.3 ± 0.21bc

DF: Days to flowering; PH: Plant height (cm); NL: Number of leaves/plant; PB: Number of primary branches/plant; SB: Number of secondary branches/plant; Prst: Number of productive stems/plant; Pods: Number of pods/plant; PL: Pods length (cm).

Effect of different steckling size on plant morphological parameters

Steckling size is one of the important plant morphological parameters to be study for better seed quality for root crops. Data regarding steckling size is presented in Table 2. Statistical analysis showed that T_1 (control- full size steckling/ no root cut) takes maximum number of days to flowering (63.33) and produced larger plants (156.33 cm) having maximum number of leaves (37.3), primary branches (23.33), secondary branches (17.00), number of productive stems (23.00) and number of pods (552.00). Similar trend was also followed by T_2 (steckling of random size) that took 55.33 days to flowering and produced plants that reached up to 110.4 cm height having 32.6 number of leaves and 7.66 primary branches, respectively.

Treatment (T_5) took significantly less number of days to produced flower (37.33) whereas in T_3 and T_8, plants with minimum height were produced (54.5 cm and 48.96 cm) and developed less number of primary branches (14.3 and 16.3), number of leaves was also found minimum in T_3 (10.00). However, a significant reduction in secondary branches was examined in T_2 (6.66). Minimum number of productive stems and number of pods/plant were observed in T_5 (7.00 and 182.33) but steckling in this treatment produced pods of maximum length (7.2 cm) (Figure 1).

Among seed related parameters (Figure 2), highest number of seeds/pod (8.66) were produced in T_7 followed by T_8 which produced 8 seeds per pod. However, minimum seeds were formed in pods of T_2 (4.33). Total seed yield/plant were significantly maximum in T_6 (18.26g) while seeds of larger size were observed in T_5 (0.45 mm) (Figures 2 and 3) and seed with highest vigor index were produced in T_3 (845) and T_7 (832.66) (Figures 2 and 4).

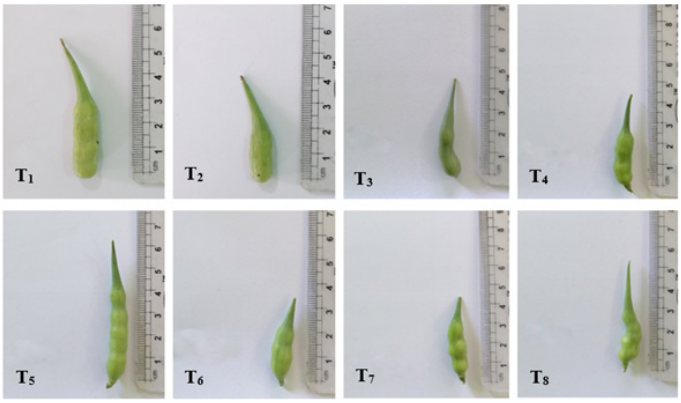

Figure 1: *Effect of different steckling size on pod length of radish cv. Mino.*

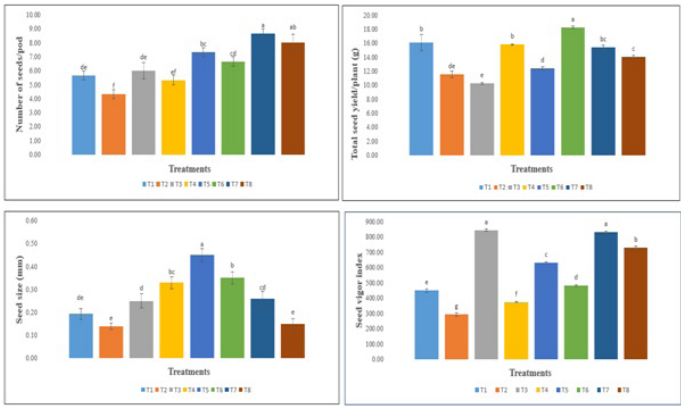

Figure 2: *Effect of different steckling size on seed yield and quality parameters of radish cv. Mino.*

Correlation analysis

Correlation is an important statistical approach to study the relationship between different traits of crop species. Correlation among different morphological (vegetative and reproductive) and seed related parameters are presented in Figure 5. In this Figure

5, box color ranges from dark blue (unit positive) as positive correlation between those traits to dark red (unit negative) as negative correlation that shows negative association among various morphological parameters. According to correlation analysis, number of productive stems showed significant and positive association with primary branches (0.75**), days to flowering (0.71**), number of pods (0.6**), plant height (0.57*), total seed yield/plant (0.55*) and number of leaves (0.38*). Days to flowering depicts positive association with number of pods (0.79**), plant height (0.73**), and number of leaves (0.53*). Number of leaves also positively correlated with secondary branches (0.56*), pod length (0.55*) and plant height (0.48*). Pod length an important yield parameter was positively associated with secondary branches (0.86**) while no of seeds exists in correlation with seed vigor (0.39*) and secondary branches (0.28). Similarly seed size also exhibited positive association with pod length (0.26) and secondary branches (0.24).

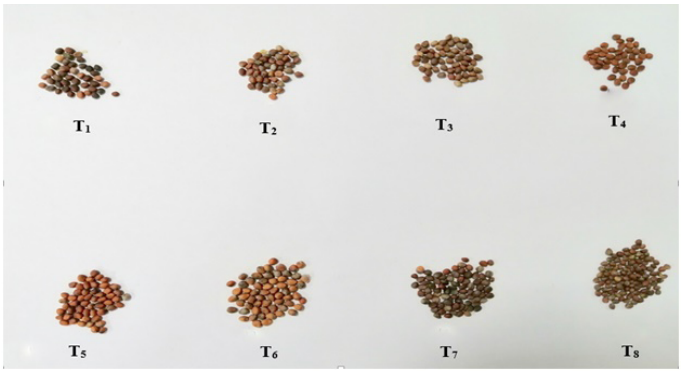

Figure 3: *Effect of different steckling size on seed size of radish cv Mino.*

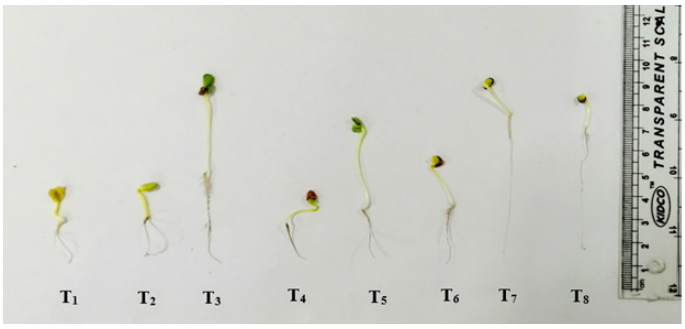

Figure 4: *Effect of different steckling size on seed vigor index of radish cv. Mino.*

Healthy, true to type and vigorous seeds are important source for better crop stand and ultimate productivity of the growers and can meet the requirements of end users. Quality seed helps in improving seed germination, seedling uniformity, genetic purity and free from seed borne pathogens (Singh and Dhillon, 2016). In radish seed production (root to seed), steckling size has significant effect on seed yield and quality. Therefore, in present study, different steckling sizes were evaluated for different seed yield and related parameters. According to research results, control treatment plant (full size steckling or no root cut) had maximum vegetative and reproductive growth (plant height, number of leaves, primary branches, secondary branches, productive stems and pods). This was attributed due to availability of large amount of nutrients, as large sized roots stored maximum quantity of food reserves thus the continuous supply of reserved food material resulted in effective growth and development (Hamid *et al.*, 2002) at early or vegetative stage of the crop. However, in other treatments, significant reduction in growth parameters is due to the cutting of fleshy roots which leads to reduction in stored food. Further root cutting also increased the susceptibility of freshly cut roots to root rot pathogen which affect the growing plant development (Hoque *et al.*, 2015). Despite having maximum vegetative and reproductive growth by control treatment (T_1) and T_2 (random root cut), both treatments showed delay in flowering whereas treatment (T_5) with a steckling length of L= 15cm caused early flowering which could be due to rapid growth because of continuous food supply from longer steckling till the adventitious root formation (Kumar *et al.*, 2007). Similar results were observed in carrot seed production, where steckling of 20 cm size takes less number of days to flowering as compared to flowering in steckling of size 5 cm (Mohammad *et al.*, 2013). Seed quality is determined by seed size and seed vigor (Noor *et al.*, 2020) thus in present research seed related parameters such as number of seeds/pod, seed size, weight and vigor increased in treatment (T_6 and T_7) with wider steckling size and in T_5 that has longer stecklings. This is because of the ample supply of nutrients present abundantly in longer and wider stecklings (Kumar *et al.*, 2017). Despite of maximum increase in vegetative parameters in T_1, T_2 andother treatments significant reduction in seed related parameters was observed, which may be due to inadequate supply of nutrients during early growth and development of flowering stalk or incidence of pithiness or black core that affect the reproductive ability of plants due to disturbance in reserved food supplyand causes changes in seed yield and quantity. As in full sized steckling, there is no selection of desirable, disease free, true to type roots that ultimately affect the seed plant growth and yield. That's why this method is not applicable for nucleus, breeder and

foundation seed productionin any seed production Program (Kumar *et al*., 2007). It was also observed that in extra wide stecklings, all growth parameters showed reduction which was due to the development of pith tissues in over mature roots (Tyagi and Khaire, 2018).

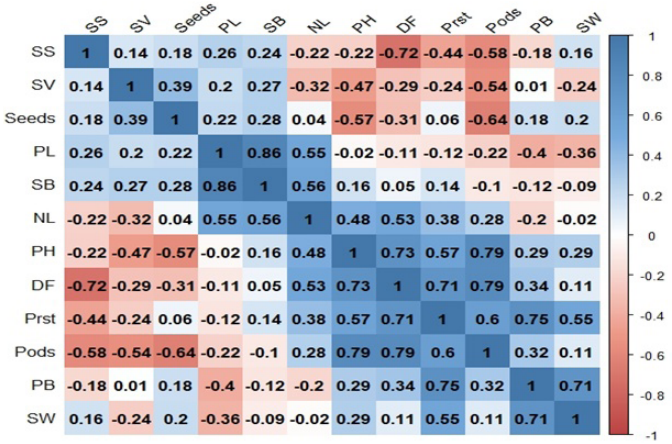

Figure 5: *Correlation analysis for morphological traits (vegetative and reproductive) in radish cv. Mino. SS: seed size; SV: seed vigor index; Seeds: number of seeds/pod; PL: pod length; SB: number of secondary branches; NL: number of leaves; PH: plant height; DF: days to flowering; Prst: number of productive stems; Pods: number of pods/plant; PB: primary branches; SW: total seed yield/plant.*

As growth and yield parameters like number of productive stems, days to flowering, plant height, number of pods and seed weight depends upon stored food material in roots of different sizes, therefore they are positively correlated with each other (Mohammad *et al*., 2013). Similarly, number of leaves also exist in positive association with days to flowering, plant height, secondary branches and number of pods per plant because of maximum photosynthesis due to more number of leaves that produced abundant food and supplied it to different developing parts of the plants which resulted in improved plant growth and ultimately in increased seed yield (Hamid *et al*., 2002).

Conclusions and Recommendations

Seed production of vegetables needs special skills and techniques to get pure and healthy seed. From present research, it was concluded that economical radish seed production with better quality seed can be achieved by using wider stecklings size, as they tookless number of days to flowering and produced seed of larger size, weight and higher vigor. Furthermore, both shorter and extra wider stecklings are not recommended due to poor quality seed production. It is also recommended that root crops should be uprooted and replanted for better and quality seed production instead of leaving plants in field for seed production without uprooting and selecting proper stecklingsize for better quality and vigorous seed production with higher yield.

Novelty Statement

Seed production technology of radish is a neglected sector in Pakistan which leads to import of seeds that enhances the import bill of the country. Radish seed quality, vigour and yield depend upon various factors, among which steckling size is one of the important character. As in Pakistan, there is no proven and recommended seed production technology in radish. Therefore, in present research, different steckling sizes were studied in order to standardize seed production technology. This study will prove to be useful for quality and vigorous seed production.

Author's Contribution

AM and RA: Conceived the research idea.
AM and MSN: Conducted research and wrote manuscript.
SS and SA: Helped in data collection.
SRA: Critically reviewed and edited the manuscript.
RA and DI: analyzed data and helped in writing manuscript.
All authors discussed the results and contributed to final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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