

GROWTH AND DRY MATTER PARTITIONING IN MAIZE AS AFFECTED BY SEED PRIMING TECHNIQUES AND FORMS OF POULTRY MANURE AT DIFFERENT PHENOLOGICAL STAGES

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Article Info



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Abstract

A two year research was conducted at the Agronomy Research Farm, University of Agriculture Peshawar to assess the potential of seed priming and poultry manure in enhancing maize growth, development, and yield. The aim was to identify effective, low-cost strategies for improving crop performance under field conditions. The study was laid out in a randomized complete block design with three replications and two factors: seed priming (control, hydro-, halo-, solid matrix, and osmo-priming) and poultry manure forms (control, fresh, open heap, and ditch decomposed). It was revealed that days to tasseling, silking, and maturity were significantly influenced by seed priming, poultry manure, and year, with later development observed in 2022. Osmo-priming led to earlier tasseling, silking, and maturity, while decomposed poultry manure treatments tended to delay phenological stages. The greatest leaf area (3936 cm²) and tallest plants (237 cm) were recorded under osmo-priming, while ditch-decomposed poultry manure also contributed positively to these parameters. In contrast, emergence m⁻² and the number of leaves per plant were not significantly affected by treatments or year. Dry matter accumulation at both silking and physiological maturity stages was significantly enhanced by seed priming and poultry manure. The highest dry matter production at silking (99.4 g plant⁻¹) and maturity (217 g plant⁻¹) was achieved with osmo-priming, while ditch-decomposed manure yielded the highest biomass among organic amendments. Crop growth rate during both emergence to tasseling and tasseling to maturity was greatly affected by seed priming, manure forms, and year. Osmo-priming and ditch-decomposed manure consistently produced the highest CGR values. It was settled that osmo-priming combined with ditch-decomposed poultry manure significantly enhanced maize growth, dry matter accumulation, and crop growth rate. This low-cost strategy is recommended for improving maize productivity under field conditions.

Keywords:

phenology, osmo-priming, nutrient management, organic amendments, biomass accumulation.

Introduction

Maize is one of the most important cereal crops globally, cultivated across a wide range of agro-ecological zones and serving as a staple food, feed, and industrial raw material. It ranks among the top three cereal crops in Pakistan, with a cultivated area of 1.7 million hectares and production of 10.9 million tons in 2023 (MNFS&R, 2024). Despite the availability of high-yielding hybrids, the potential productivity of maize remains underexploited due to poor crop establishment and suboptimal biomass allocation throughout its growth stages. Achieving optimum crop growth and final yield in maize is closely linked to efficient dry matter partitioning across different phenological stages, from early vegetative development to grain filling. Dry matter partitioning refers to the distribution of assimilated biomass to various plant organs (leaves, stems, roots, and grains), which is a key determinant of plant architecture and yield potential. This partitioning is largely influenced by the physiological status of the crop and is sensitive to agronomic interventions such as seed treatments and nutrient sources.

Seed priming is a pre-sowing physiological technique that enhances germination performance and early seedling vigor, especially under stressful conditions. It initiates early metabolic processes in the seed without actual radicle protrusion, allowing quicker and more uniform emergence upon sowing (Han and Yang, 2015). Primed seeds often show accelerated germination, improved stand establishment, and enhanced early root and shoot growth, leading to better dry matter accumulation during the critical early stages of crop development (Harris et al., 2007). Techniques such as hydro-priming, osmo-priming, and halo-priming have been shown to improve seedling vigor and promote stress tolerance in maize and other field crops (Farooq et al., 2019; Kipriyanov and Savinykh, 2023). In parallel, nutrient availability plays a vital role in influencing dry matter production and its subsequent partitioning among plant organs. Among organic nutrient sources, poultry manure is particularly valuable due to its balanced content of macro- and micronutrients, rapid mineralization rate, and consistent nutrient release throughout the crop growth period. Studies have shown that poultry manure can enhance leaf area development, cob size, grain number, and overall biomass accumulation in maize (Farhad et al., 2009; Bilal et al., 2017). When applied in appropriate forms, poultry manure supports the sustained supply of nutrients, which is crucial for maintaining source-sink balance during the phenological transitions from vegetative to reproductive stages.

The timing and magnitude of dry matter accumulation and its translocation in maize are highly dependent on the crop's phenological stage. During early vegetative growth, dry matter is primarily allocated to leaf and root development, whereas in the later stages, particularly during grain filling, the focus shifts toward reproductive structures. Understanding how agronomic interventions such as seed priming and organic nutrient sources influence these patterns is crucial for optimizing yield. However, the influence of seed priming techniques and poultry manure types on the temporal and spatial distribution of dry matter remains insufficiently explored, especially under field conditions that reflect practical stress scenarios. Therefore, this study was conducted to evaluate the effects of different seed priming techniques on early growth and dry matter accumulation, assess the impact of various forms of poultry manure on dry matter partitioning at key phenological stages, and investigate their interaction in determining dry matter allocation patterns and their relationship with yield components in maize.

Materials and Methods

Experimental design and treatment details

The experiment entitled “Influence of seed priming and poultry manure application on growth and yield of maize” was carried out at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2021 and 2022. The experiment was performed in a randomized complete block design having three replications. The experiment consisted of two factors i.e. seed priming [control (no priming), hydro priming, halo priming, solid matrix priming and osmo-priming] and forms of poultry manure (PM) [control (no PM), fresh form, stored in open heap and ditched decomposed]. Seeds were primed using four techniques for 12 hours at room temperature: hydro-priming (1 L distilled water), halo-priming (50 g L⁻¹ NaCl solution), osmo-priming (100 g L⁻¹ PEG solution), and solid matrix priming using 1 kg press mud (a sugar industry byproduct) moistened with 5 L distilled water. After priming, seeds were sieved and air-dried for sowing. Poultry manure was stored 21 days in open area for open heap decomposition, while for ditch decomposition it was stored in ditch for 21 days. All the forms of poultry manure were applied at the rate of 5 tons ha⁻¹ to the field 15 days pre plantation of the crop. A plot size of 3.5 m x 4.5 m was maintained. There were six rows in each plot. Row to row distance was 75 cm and plant to plant distance was 25 cm. All other agronomic practices were kept uniform for all the experimental units throughout the growing season.

Phenological observations

Phenological observations were recorded based on key developmental stages of maize. Days to emergence were calculated from the sowing date to the point when 75% of the seedlings had emerged in each plot. Days to tasseling were determined as the number of days from sowing to when tassels appeared on 75% of the plants. Similarly, days to silking were recorded from the sowing date to the visibility of silks in 75% of the plants. Days to physiological maturity were noted when 75% of the plants reached maturity, indicated by the formation of a black layer at the base of the kernels.

Growth observations

Data on emergence per square meter (emergence m⁻²) were collected by counting the number of emerged plants at three randomly selected one-meter row segments in each plot. The average was calculated and used in the formula: Emergence m⁻² = (Number of plants counted) / (Row length × Row-to-row distance) × 1 m². For the number of leaves per plant, five plants were randomly selected from each plot, and their leaves were counted to determine the average. Leaf area per plant (cm²) was calculated by measuring the length and width of five leaves from each of the five randomly selected plants per plot. The leaf area was then computed using the formula by Stewart and Dwyer (1999): Leaf area plant⁻¹ = Number of leaves per plant × Average leaf length × Average leaf width × 0.75. Plant height was recorded at the tasseling stage by measuring five randomly selected plants in each plot with a meter rod, and the average height was determined.

Crop growth rate at different phenological stages

For Crop growth rate (CGR), five plants were randomly sampled from each plot at two successive growth stages: from emergence to tasseling, tasseling to physiological maturity. The plants were separated into their components (leaves, stalks, and ears), sun-dried, and weighed using a digital balance. CGR was then calculated using the following equation:

$$\text{CGR (g m}^{-2} \text{ day}^{-1}) = (W_2 - W_1) / (T_2 - T_1)$$

Where W_1 and W_2 represent the total dry matter (g m^{-2}) at the first and second sampling dates respectively, and $T_2 - T_1$ is the number of days between the two sampling intervals. The values were averaged to obtain CGR for each phenological stage.

Dry matter partitioning (g plant^{-1}) at different phenological stages

Dry matter partitioning (g plant^{-1}) at silking and physiological maturity stages was determined by randomly harvesting five plants from each plot at the respective stages. The harvested plants were separated into ears, stalks, and leaves. Each component was sun-dried thoroughly and weighed using a digital balance. The average dry weights of these components were then recorded to represent the partitioned dry matter at each phenological stage.

Statistical analysis

The data recorded were analyzed statistically using analysis of variance techniques appropriate for randomized complete block design with split plot arrangement. Means were compared using LSD test at 0.05 level of probability, when the F-value is significant (Jan et al., 2009).

RESULTS

Phenological observations

Seed priming significantly influenced the number of days to emergence, while poultry manure forms, year, and all interactions had no significant effect. All priming treatments except hydro-priming resulted in the shortest emergence time (5 days), while the longest was recorded in the unprimed control (7 days). Days to tasseling were significantly affected by seed priming, poultry manure, and year, with tasseling delayed in 2022 (57 days) compared to 2021 (56 days). The shortest time to tasseling (56 days) was observed with osmo-, halo-, and solid matrix priming, and the longest (58 days) in the control. Among poultry manure treatments, the shortest tasseling duration (55 days) occurred in the control, while the longest (57 days) was observed with decomposed manure. A similar pattern was recorded for days to silking, which were significantly affected by seed priming, poultry manure, and year. The shortest silking period (63 days) occurred with all priming treatments except hydro-priming, and the longest (65 days) in the control. Among poultry manure treatments, the shortest silking period (62 days) was recorded in the control and the longest (65 days) with decomposed manure. Days to physiological maturity were significantly influenced by seed priming, manure forms, and year, with delayed maturity observed in 2022 (87 days) compared to 2021 (85 days). The shortest maturity period (85 days) was recorded with osmo- and halo-priming, and the longest (88 days) in the control. For poultry manure, the shortest maturity duration (85 days) was recorded in the control, while the longest (87 days) occurred with ditch-decomposed manure.

Table 1. Phenological observations of maize as influenced by seed priming techniques and types of poultry manure in 2021 and 2022.

Treatment	Days to Emergence	Days to Tasseling	Days to Silking	Days to Maturity
Seed Priming (SP)				
Control	7.0 a	58 a	65 a	88 a
Hydro Priming	6.0 b	57 b	64 b	86 b
Halo Priming	5.0 c	56 c	63 c	85 c
Solid Matrix Priming	5.0 c	56 c	63 c	86 b
Osmo Priming	5.0 c	56 c	63 c	85 c
Poultry Manure (PM)				
Control	6	55 c	62 c	85 c
Fresh	6	56 b	63 b	86 b
Open Decomposed	6	57 a	64 a	86 b
Ditch Decomposed	6	57 a	64 a	87 a
Year (Y)				
2021	6	56 b	63 b	85 b
2022	6	57 a	64 a	87 a
LSD (0.05)	0.3	1	1	1
Significance				
SP	**	**	**	**
PM	NS	**	**	**
Y	NS	*	*	*
SP × PM	NS	NS	NS	NS

Means followed by different letters within each treatment differ significantly at the 5% level (LSD test). SP = Seed Priming, PM = Poultry Manure, Y = Year. LSD (0.05) shows the least significant difference. NS = Non-significant; * = Significant at 5% level; ** = Significant at 1% level.

Growth Observations

Emergence m⁻² was not affected by seed priming techniques, forms of poultry manure, year, or their interactions, indicating uniform emergence across treatments. Similarly, the number of leaves per plant showed no significant variation due to seed priming, poultry manure application, year, or any interaction effects, suggesting that these factors did not influence leaf production in maize. However, leaf area per plant was significantly affected by seed priming, poultry manure forms, and year, while all interactions remained non-significant. Greater leaf area was observed in 2022 (3861 cm²) compared to 2021 (3591 cm²). Among priming treatments, the highest leaf area (3936 cm²) was recorded with osmo-priming (PEG-

6000), while the lowest (3445 cm²) was observed in the control. Regarding poultry manure, the highest leaf area (3785 cm²) was recorded with ditch-decomposed poultry manure, and the lowest (3640 cm²) with no manure application. Plant height was also significantly influenced by seed priming, poultry manure forms, and year, with no significant interaction effects. Taller plants were recorded in 2022 (229 cm) compared to 2021 (213 cm). The highest plant height (237 cm) was recorded with osmo-priming, and the lowest (204 cm) in the unprimed control. Among manure treatments, the highest plant height (239 cm) was recorded with ditch-decomposed poultry manure, while the lowest (205 cm) was observed with no manure application.

Table 2. Growth observations of maize as influenced by seed priming techniques and types of poultry manure in 2021 and 2022.

Treatment	Emergence m ⁻²	Leaves plant ⁻¹	Leaf area plant ⁻¹ (cm ²)	Plant height (cm)
Seed Priming (SP)				
Control	20.6	19.0	3445 d	204 d
Hydro Priming	20.8	18.9	3649 c	214 c
Halo Priming	21.0	18.5	3710 c	221 b
Solid Matrix Priming	20.4	19.0	3892 b	228 a
Osmo Priming	19.1	19.2	3936 a	237 a
Poultry Manure (PM)				
Control	19.1	19.0	3640 b	205 d
Fresh	21.5	19.2	3714 ab	214 c
Open Decomposed	20.7	18.5	3766 a	227 b
Ditch Decomposed	20.3	19.0	3785 a	239 a
Year (Y)				
2021	20.7	19.0	3591	213
2022	20.1	18.9	3861	229
LSD (0.05)	NS	NS	101 (SP), 90 (PM)	6
Significance				
SP	NS	NS	**	**
PM	NS	NS	**	**
Y	NS	NS	*	**
SP × PM	NS	NS	NS	NS

Means followed by different letters within each treatment differ significantly at the 5% level (LSD test). SP = Seed Priming, PM = Poultry Manure, Y = Year. LSD (0.05) shows the least significant difference. NS = Non-significant; * = Significant at 5% level; ** = Significant at 1% level.

Dry matter partitioning and crop growth rate at different phenological stages

Total dry matter production at both silking and physiological maturity stages of maize was significantly influenced by seed priming techniques and poultry manure forms. At silking, dry matter accumulation was higher in 2022 ($97.3 \text{ g plant}^{-1}$) than in 2021 ($94.1 \text{ g plant}^{-1}$). Osmo-priming resulted in the highest dry matter ($99.4 \text{ g plant}^{-1}$), while the lowest ($91.0 \text{ g plant}^{-1}$) was observed in the unprimed control. Among poultry manure treatments, ditch-decomposed manure produced the highest dry matter ($97.9 \text{ g plant}^{-1}$), and the lowest ($92.4 \text{ g plant}^{-1}$) was recorded for control. A significant interaction between seed priming and manure form at silking revealed that osmo-priming combined with decomposed poultry manure (ditch or open) produced the maximum dry matter. At physiological maturity, seed priming and manure application continued to significantly affect dry matter accumulation, though year and interaction effects were non-significant. Osmo-priming again led to the highest dry matter (217 g plant^{-1}), and the lowest (186 g plant^{-1}) was in the control. Ditch-decomposed poultry manure yielded the highest dry matter (226 g plant^{-1}), while no manure resulted in the lowest (176 g plant^{-1}). Crop growth rate (CGR) from emergence to tasseling and from tasseling to maturity was significantly affected by seed priming, manure forms, and year, with no significant interaction effects. The highest CGR during emergence to tasseling ($14.8 \text{ g m}^{-2} \text{ day}^{-1}$) was recorded with osmo-priming, and the lowest ($12.5 \text{ g m}^{-2} \text{ day}^{-1}$) with no priming. Ditch-decomposed poultry manure resulted in the highest CGR ($14.5 \text{ g m}^{-2} \text{ day}^{-1}$), while no manure gave the lowest ($12.7 \text{ g m}^{-2} \text{ day}^{-1}$). CGR was greater in 2022 ($14.1 \text{ g m}^{-2} \text{ day}^{-1}$) than in 2021 ($13.2 \text{ g m}^{-2} \text{ day}^{-1}$). During tasseling to maturity, osmo-priming again led to the highest CGR ($13.1 \text{ g m}^{-2} \text{ day}^{-1}$), and the control had the lowest ($10.4 \text{ g m}^{-2} \text{ day}^{-1}$). The highest CGR from manure treatments ($13.0 \text{ g m}^{-2} \text{ day}^{-1}$) was with ditch-decomposed manure, while the lowest ($10.3 \text{ g m}^{-2} \text{ day}^{-1}$) was without manure. Year-wise, CGR during this phase was also higher in 2022 ($12.1 \text{ g m}^{-2} \text{ day}^{-1}$) than in 2021 ($11.4 \text{ g m}^{-2} \text{ day}^{-1}$).

Table 3. Dry Matter Accumulation and Crop Growth Rate of Maize as Influenced by Seed Priming and Poultry Manure

Treatment	Dry Matter at Silking plant ⁻¹)	Dry Matter at Maturity plant ⁻¹)	CGR (Emergence to Tasseling) (g m ⁻² day ⁻¹)	CGR (Tasseling to Maturity) (g m ⁻² day ⁻¹)
Seed Priming (SP)				
Control	91.0 e	186 c	12.5 c	10.4 d
Hydro Priming	93.6 d	199 b	13.1 bc	11.3 c
Halo Priming	97.6 b	206 b	14.2 ab	11.8 bc
Solid Matrix Priming	96.9 c	211 ab	13.9 b	12.4 ab
Osmo Priming	99.4 a	217 a	14.8 a	13.1 a
Poultry Manure (PM)				
Control	92.4 c	176 d	12.7 c	10.3 d
Fresh	95.7 b	199 c	13.5 b	11.6 c
Open Decomposed	96.8 ab	215 b	14.0 ab	12.3 b
Ditch Decomposed	97.9 a	226 a	14.5 a	13.0 a
Year (Y)				
2021	94.1	198	13.2	11.4
2022	97.3	210	14.1	12.1
LSD (0.05)	2.0 (SP), 1.8 (PM)	10 (SP), 9 (PM)	0.8 (SP), 0.7 (PM)	0.6 (SP), 0.5 (PM)
Significance				
SP	**	**	**	**
PM	**	**	**	**
Y	**	NS	*	*
SP × PM	**	NS	NS	NS

Means followed by different letters within each treatment differ significantly at the 5% level (LSD test). SP = Seed Priming, PM = Poultry Manure, Y = Year. LSD (0.05) shows the least significant difference. NS = Non-significant; * = Significant at 5% level; ** = Significant at 1% level.

Discussion

The study demonstrated that seed priming significantly reduced the number of days to emergence in maize, confirming its role in enhancing early germination. This aligns with previous research highlighting seed

priming as an effective pre-sowing strategy to activate metabolic processes that accelerate seedling emergence (Farooq et al., 2006). Early emergence is particularly advantageous in optimizing crop stand and yield potential under time-sensitive agronomic conditions. Conversely, different poultry manure forms had no significant impact on emergence timing, suggesting that organic amendments may not influence initial germination processes under the conditions of this study. While poultry manure is valued for improving soil fertility, its effects on germination are context-dependent and influenced by factors such as decomposition level, application rate, and soil conditions (Humnessa et al., 2023). No significant year or interaction effects were observed for days to emergence, indicating consistency in emergence timing across environmental conditions during the study period. However, variations in environmental factors like temperature and soil moisture are known to influence maize emergence (Reynolds et al., 1994) and may have been minimized due to controlled experimental conditions. In contrast, seed priming and poultry manure application significantly influenced the timing of tasseling, silking, and physiological maturity. Priming treatments such as osmo- and halo-priming accelerated these developmental stages, likely by enhancing early growth and metabolic activity, as supported by previous studies (Ashraf et al., 2011; Cai et al., 2020; Li et al., 2021). Poultry manure, particularly in decomposed forms, delayed reproductive events, possibly due to gradual nutrient release and shifts in soil microbial activity, affecting plant hormonal balance and phenology (Peng et al., 2012). These findings emphasize the dual importance of seed conditioning and organic nutrient management in regulating maize development and optimizing growth stage transitions.

The results of this study indicated that neither seed priming nor the application of different forms of poultry manure had a statistically significant effect on emergence m^{-2} of maize. This suggests that under the given experimental conditions, these treatments did not influence emergence density. This finding contrasts with earlier studies that report enhanced germination and emergence due to seed priming (Kaya et al., 2006), likely due to variations in crop species, environmental conditions, or seed quality. Likewise, the absence of a significant effect from poultry manure may reflect limited influence of organic amendments on early emergence under the conditions of this trial, despite their known role in improving soil fertility (Humnessa et al., 2023). Likewise, leaves per plant were not significantly affected by either seed priming or poultry manure application. While prior studies have linked seed priming to increased early vigor and leaf development (Hameed et al., 2013), the lack of response here may relate to maize genotype, priming duration, or environmental uniformity.

The non-significant influence of poultry manure on leaf number also diverges from expectations based on its nutrient-enriching properties (Peng et al., 2022), potentially due to the time required for organic nutrients to become plant-available. In contrast, leaf area per plant was significantly improved by both seed priming and poultry manure application. Osmo-priming and solid matrix priming produced the largest leaf areas, likely due to enhanced seedling vigor and nutrient uptake (Ashraf et al., 2011; Hameed et al., 2013). Among manure treatments, decomposed poultry manure (ditch or open) resulted in greater leaf expansion than fresh manure, emphasizing the importance of nutrient availability and microbial stability in organic fertilizers (Peng et al., 2022). Plant height was also significantly influenced by both seed priming and poultry manure. Osmo-priming and solid matrix priming produced taller plants, consistent with reports that seed priming enhances cell division and elongation during early growth (Singh et al., 2021). Similarly, poultry manure, particularly in decomposed forms, contributed to greater plant height, with the tallest plants observed under ditch-decomposed manure. This reflects the role of sustained nutrient release and improved soil structure in supporting vegetative growth (Nyombayire et al., 2019).

The total dry matter production at both silking and physiological maturity stages in maize was greatly influenced by seed priming techniques and various forms of poultry manure. These results align with previous research highlighting the role of seed priming in enhancing plant vigor, biomass accumulation, and overall physiological performance (Ibrahim et al., 2016; Jisha and Puthur, 2016). Among the treatments, osmo priming consistently resulted in the highest dry matter production, followed by halo and solid matrix priming. The improved performance of these treatments suggests that specific priming methods activate metabolic processes prior to germination, fostering better nutrient uptake and stronger vegetative growth, ultimately translating into greater dry matter accumulation at critical growth stages. Similarly, the application of poultry manure significantly enhanced total dry matter production, particularly when decomposed manure (either in a ditch or open form) was used. These treatments outperformed fresh manure and control plots with no manure, reinforcing the importance of organic matter decomposition for effective nutrient mineralization and uptake (Ghimire et al., 2019; Ogunwole et al., 2021). Decomposed poultry manure likely improved soil structure and microbial activity, contributing to better nutrient availability and supporting greater biomass production in maize.

The same phenomenon was reflected for CGR measurements. Both seed priming and poultry manure significantly influenced CGR during the periods from emergence to tasseling and tasseling to physiological maturity. Osmo priming again exhibited the highest CGR across both stages, indicating sustained growth momentum facilitated by early metabolic activation. This finding supports previous work emphasizing the contribution of seed priming to improved photosynthetic efficiency and biomass partitioning (Hameed et al., 2013). Likewise, ditch-decomposed poultry manure led to the highest CGR, followed by open-decomposed manure. These results highlight the synergistic role of organic amendments in maintaining nutrient availability over time, especially during critical reproductive phases when plant nutrient demand intensifies (Li et al., 2021). In contrast, control treatments lacking manure or seed priming exhibited the lowest CGR values, underscoring the importance of both seed and soil management in enhancing crop growth dynamics. Together, these findings confirm that both seed priming particularly osmo and halo techniques and the use of well-decomposed poultry manure are effective strategies for enhancing dry matter production and sustaining crop growth rates in maize.

Conclusion

It was demonstrated that both seed priming techniques and poultry manure forms significantly influenced maize phenology, growth parameters, dry matter accumulation, and crop growth rate. Among seed priming treatments, osmo-priming consistently improved early emergence, reduced the time to tasseling, silking, and maturity, and resulted in the highest leaf area, plant height, dry matter production, and CGR. Similarly, the application of ditch-decomposed poultry manure significantly enhanced plant height, leaf area, dry matter accumulation, and CGR compared to fresh or non-decomposed manure. Yearly variations were evident, with better growth and development observed in 2022. The study concludes that combining osmo-priming with well-decomposed poultry manure is an effective strategy to enhance maize growth and productivity under field conditions.

- Acknowledgement
- Author contribution
- Conflict of interest
- Funding

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