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VERMICOMPOST ENHANCES SALINE TOLERANCE IN PEANUT (*Arachis hypogaea* L.)

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Abstract: Peanut is an oilseed legume plant with multi-purpose uses that contains many bioactive components, including polyphenols, phenolics, and flavonoids. It is one of the main foodstuffs, both in meeting protein deficiencies and in meeting high energy needs. This study investigated the effects of vermicompost fertilizer application on chlorophyll content and yield parameters of peanuts grown under saline stress in climate room conditions. Root weight, root length, stem weight, stem length, leaf weight, leaf number, and chlorophyll content values were determined in the first developmental period of the plant in the experiment, which was established with three replications according to the randomized plots experimental design. As a result of the study, statistical differences were determined between control and vermicompost treatments under high saline stress conditions (300 mM). The results obtained from the vermicompost treatment, especially in stem and root weights, prove this treatment's usefulness. The principal component analysis (PCA) clustered all parameters according to applications. Correlation analysis revealed significant relationships, especially for vermicompost treatment. It is thought that the information obtained from the experimental results will be helpful to entrepreneurs investigating the saline stress resistance of peanuts.

Keywords: Abiotic stress, Salt, Chlorophyll, Physiological characteristics, *Arachis hypogaea*

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1. Introduction

The rapid increase in the world population causes insufficient food in terms of calories and other nutritional values (Ali et al., 2020). Food safety cannot be ensured, and the yield values of the plants decrease with the changing climatic conditions worldwide (Yılmaz et al., 2022). If economically sustainable agriculture is to be provided and farmers are to be given a chance to survive on the farm, agricultural management and production paradigms should be changed, while modern agrarian practices should be implemented (Yılmaz et al., 2021a).

Oilseed crops rich in primary and secondary metabolites (minerals, vitamins, carbohydrates, protein, fat, antioxidants, and phenolics) constitute an essential raw material source for animal and human nutrition and the industrial sector (Yılmaz et al., 2021a). They are also economically, socially, and environmentally significant as they provide food, feed, and raw materials (Can et al., 2021). These crops can adapt to different agricultural conditions of the world, from temperate to tropical regions (Yılmaz et al. 2021b). Approximately 8% of the world's oilseed needs are met by peanut agriculture (Yılmaz et al., 2021c). Peanut (*Arachis hypogaea* L.) is an oil-producing legume plant grown in subtropical and semi-arid tropical regions of the world, especially between 40° north and 40° south locations (Yılmaz and Çiftçi, 2021). Peanuts are among the world's leading oilseed crops, with an annual production of forty-five million tons, cultivated on 26 million hectares of land in approximately 120 countries (Singh et al., 2021). Peanuts are a source of antioxidants, vitamins, minerals, and health-improving bioactive compounds such as arginine, tocopherol, resveratrol, etc., and hence are touted as a functional food (Variath and Janila, 2017). Peanut seeds contain an excellent rate of protein (16-36%), oil (35-54%), and carbohydrates (10-20%). They also contain high levels of Ca, Mg, P, vitamin E, folic acid, niacin, riboflavin, amino acids, and resveratrol (Singh et al., 2021). In this respect, it is highly important for human nutrition.

Abiotic stress factors are significant physiological events that negatively affect crop productivity (Yılmaz et al., 2022). Numerous studies have been conducted to reduce the harmful effects of abiotic stress factors on plants (Yavaş et al., 2020). Soil salinity can reduce plants' growth rate (Doğru and Canavar, 2020). Saline stress is one of the most important abiotic factors limiting agricultural productivity worldwide. Saline stress also reduces photosynthetic capacity because of causes the part affinity and stomata osmotic pressure. Plants can also suffer from general nutrient uptake and metabolic disorders due to saline stress (Yılmaz and Kulaz, 2019).

Maintaining and developing a quality soil structure is one of the most important goals for sustainable agriculture

(Ayhan and Kulaz, 2016). Vermicompost fertilizers contain worm secretions, mycorrhizal fungi, asymbiotic, symbiotic microorganisms, and actinomycetes. The production and use of vermicompost have become a new trend today (Sönmez and Gülser, 2021). It has been reported that vermicompost treatments positively affect product quantity and quality in many field crops such as corn (Durukan et al., 2020), potato (Yourtchi et al., 2013), and chickpea (Uçar et al., 2020). This situation manifests itself in the form of significant increases in yield criteria as a reflection of the enhancements in the chemical and physical characteristics of the soils with vermicompost treatments (Sönmez and Gülser, 2021). Thanks to these benefits, it has also been seen in some studies that the plant provides tolerance against saline stress (Liu et al., 2019; Ding et al., 2021; Beyk-Khormizi et al., 2022). The primary purpose of this study is to prove that vermicompost fertilizers are an alternative factor in preventing saline stress in the peanut.

2. Materials and Methods

This research was carried out at Bolu Abant İzzet Baysal University, Faculty of Agriculture, Department of Field Crops. Seeds were sowed in pots and grown under controlled climate room conditions. Plants were harvested after a 3-week growing period. The study was set up in a randomized plot design with three replications.

2.1. Plant Material

The seeds of the EFSANE registered peanut variety were supplied from the Progen seed company.

2.2. Saline Application

Peanuts were gradually exposed to saline stress for five days with 150 mM and 300 mM NaCl after a 2-week growing period (Yılmaz and Çiftçi, 2021).

2.3. Vermicompost Treatment

Niksolfarm brand liquid vermicompost, supplied from Dost Organic Tarım (Bolu, Türkiye) (Table 1), was diluted 50% and applied twice, one week before and two days after saline application in the form of a spray to leaves and stems.

2.4. Physical Analyses

2.4.1. Stem length

The distance from the soil level to the top leaf extension of the plants was measured as stem length in cm.

2.4.2. Root length

After the plant was removed from the soil, the part of the root zone up to a point on the soil surface was cut. The root zone was measured in cm from this point to the lowest root extension.

2.4.3. Stem weight

The part of the plant above the ground was considered the stem region and was weighed on a precision scale and calculated in g/plant.

2.4.4. Root weight

The part of the plant under the ground was considered as the root zone and was weighed on a precision scale and calculated in g/plant.

2.4.5. Number of leaves

All leaves of plants were counted as pieces/plant calculated.

2.4.6. Leaf weight

The weights of the counted leaves were weighed on a precision scale and calculated in g/plant.

2.5. Chlorophyll Content

Chlorophyll content measurements were made from the middle leaves of the plant with the 'spad' unit using the 'Apogee MC 100 Chlorophyll Concentration Meter' device.

2.6. Statistical Analysis

Statistical analyzes of the findings were made with the R studio program. The student's t-test ($\alpha = 0.05$) was used to determine the difference between applications.

3. Results and Discussion

There were statistical differences in terms of all parameters between saline doses in the study. Statistical differences were in all parameters except leaf number and chlorophyll in vermicompost treatment. Additionally, only chlorophyll content, leaf, and stem weights were statistically different in vermicompost saline interaction (Table 2).

Table 1. Chemical and physical ingredients of Niksolfarm vermicompost fertilizer

Property	Unit	Value	Property	Unit	Value
Organic matter	%	6.88	Organic nitrogen	%	0.84
Total phosphorus pentaoxide	%	0.85	Organic carbon	%	5.29
pH		5.20	Nickel (Ni)	mg/kg	0.03
Water soluble potassium oxide	%	0.17	Cadmium (Cd)	mg/kg	0.15
Total nitrogen	%	0.93	Zinc (Zn)	mg/kg	0.18
Carbon/nitrogen determination	%	5.69	Lead (Pb)	mg/kg	0.21
Total humic+Fulvic acid	%	7.58	Quicksilver (Hg)	mg/kg	<0.01
Electrical conductivity (EC)	ds/m	2.52	Chromium (Cr)	mg/kg	0.19
Total free amino acid	(%)	1.00	Tinnen (Sn)	mg/kg	<0.01
Alginic acid	%	0.20	Copper (Cu)	mg/kg	0.05

Table 2. Statistical difference reflections of vermicompost treatment and saline doses to parameters

Trait	$F_{vermicompost}$	F_{saline}	$F_{vermicompost \times saline}$
Leaf area index	60.47****	276.03****	2.05ns
Leaf number	0.44ns	50.78****	2.11ns
Leaf weight	29.31***	488.99****	91.18****
Root length	60.06****	21.76****	1.18ns
Root weight	16.78**	16.45***	0.26ns
Stem length	7.95*	69.62****	1.04ns
Stem weight	5.13*	240.77****	5.16*
Chlorophyll content	4.26 ns	59.17****	13.15***

3.1. Physical Analyses

The images and numerical data of the physical analysis findings obtained in the study are given in Figure 1 and Table 2. According to the results, the highest mean value in stem length was obtained from vermicompost/0 mM with 19.4 cm, and the lowest mean value was obtained from 300 mM/NaCl with 10.1. For each salt dose, there was no statistically significant difference in stem length between the vermicompost and control groups. However, it was observed that stem length numerically increased with vermicompost treatment under high saline stress conditions. The highest mean value in stem weight was obtained from control/0 mM NaCl with 5.9 g/plant, and the lowest mean value was obtained from control/300 mM NaCl with 2.4 g/plant (Figure 1). A statistical difference was between the 300 mM saline doses of only vermicompost and control groups regarding stem weights. Therefore, it can be said that even though stem weight dropped in response to increasing saline stress, vermicompost treatment significantly affected stem weight compared to the control.

The highest mean value in root length was obtained from vermicompost/0 mM NaCl with 32.7 cm, and the lowest mean value was obtained from control/300 mM NaCl with 23.5 cm. There was a statistically significant difference in root lengths for each saline dose of vermicompost and control groups. With this result, it should be stated that root length increased thanks significantly to vermicompost treatment under saline stress conditions. Root weight values were obtained between 3.3 g/plant and 4.4 g/plant (Figure 1). There was a statistical difference between the 300 mM saline doses of only vermicompost and control groups regarding root weights. Therefore, it can be said that root weight increases significantly with vermicompost treatment under high saline stress conditions.

The application with the highest mean in leaf weight values was control/0 mM NaCl (3.7 g/plant), and the application with the lowest mean was control 300 mM NaCl (1.4 g/plant). In leaf weight, the saline-stress-free application of the control group was statistically superior to the saline-stress-free application of the vermicompost group. It may be explained by the fact that the plants may not be able to respond to vermicompost in terms of yield as soon as possible due to the short vegetation period.

On the other hand, as expected from the application, it was observed that the resistance to saline stress, which is the study's primary aim, gave statistically logical results at the highest saline doses. In this respect, it should be said that vermicompost treatment increased leaf number significantly under high saline stress conditions. The highest mean value in the leaf number obtained from the application of vermicompost/0 mM NaCl with 9.7 pieces/plant, and the lowest mean value was obtained from the application of control/300 mM NaCl with 5.0 pieces/plant (Figure 1). No statistically significant difference was detected in all dose comparisons. However, despite there being no statistical difference, it was observed that the leaf number was relatively higher in vermicompost treatment under 300 high saline stress conditions compared to the control. The highest mean value for leaf area index was obtained from vermicompost/0 mM NaCl with 7.84 cm^2, and the lowest mean value was obtained from control/300 mM NaCl with 3.92 cm^2. There was a statistical difference in the leaf area index for each saline dose of the vermicompost and control groups. With this result, it should be noted that the leaf area index increased thanks significantly to vermicompost treatment under saline stress conditions.

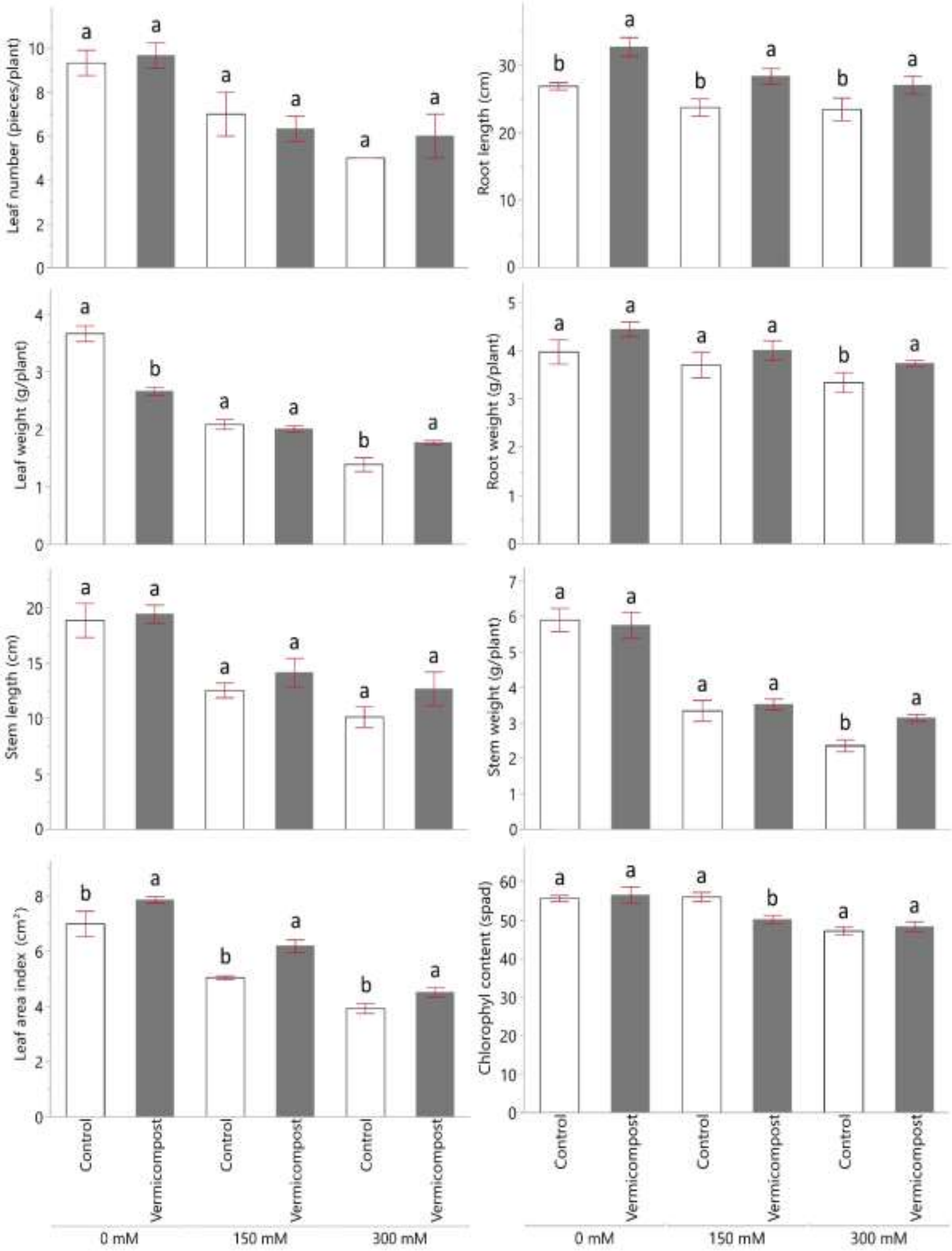

Figure 1. Statistical differences between the treatment groups of the saline doses.

It has been proven that vermicompost has a positive effect on the physiological parameters of some field crops under saline stress (Liu et al., 2019; Ding et al., 2021; Beyk-Khormizi et al., 2022). In this study, results were obtained in parallel with the literature as physiological parameters. This research observed that vermicompost application against saline stress resulted in substantial variations in physical development parameters. Especially in a recurrence of the control group exposed to high dose (300 Mm) saline stress, the yellowing and inward curling of the leaves indicates that worse results will occur in terms of peanut yield values in the later vegetation periods (Figure 2). For this reason, it is thought that vermicompost treatment can be a good alternative for yield values against saline stress that prevents the development of peanuts.

Figure 2. Peanuts grown in the study (K0: Control/0 mM NaCl K1: Control/150 mM NaCl K2: Control/300 mM NaCl V0: Vermicompost/0 mM NaCl V1: Vermicompost/150 mM NaCl V2: Vermicompost/300 mM NaCl).

3.2. Chlorophyll Content

The highest average value in chlorophyll amount was obtained from vermicompost/0 mM NaCl application with 56.4 spads, and the lowest average value was obtained from control/300 mM NaCl application with 47.2 spads. There was no statistically significant difference in stem lengths obtained from the 300 mM doses of the gruel and the control group. However, it is seen that vermicompost treatment at this dose has numerical superiority compared to the control. High chlorophyll content indicates that the plant will have more photosynthesis capacity and, therefore, higher efficiency (Kızılgeçi et al., 2017). There are many studies in which the amount of chlorophyll is in parallel with the yield values (Ghimire et al., 2015; Kandel et al., 2020; Yılmaz and Çiftçi, 2021). The values of this study are in parallel with the literature, especially for high doses.

3.3. Correlations of Parameters

Correlation analysis revealed significant associations in both control and vermicompost treatment. The highest correlation in both treatments was between leaf weight and stem weight, being r=0.99 and r=0.97 in control and vermicompost, respectively. However, the second highest correlation in vermicompost treatment was between chlorophyll content and stem weight (r=0.96), while the relationship of these traits was only r=0.66 in control as one of the weakest correlations calculated.

In general, there were higher correlations among traits in vermicompost treatment compared to the control. Interestingly, although all properties had significant positive correlations in vermicompost treatment, chlorophyll content only had a significant positive correlation with leaf features. All correlations among the studied traits are presented in Figure 3.

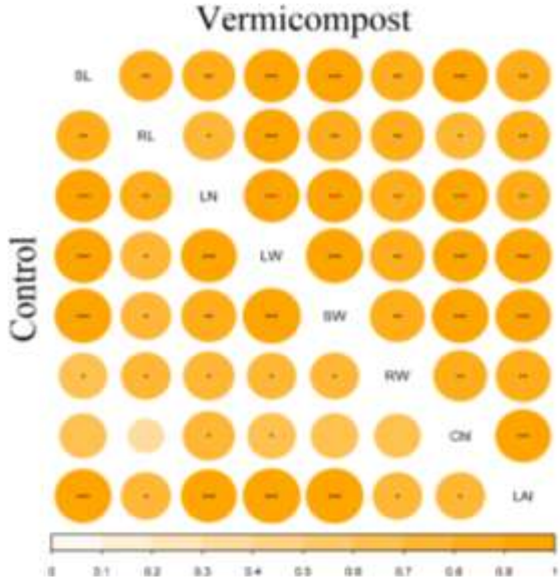

Figure 3. Correlation coefficients among parameters for both control and vermicompost treatment.

3.4. Interrelations of Parameters and Applications

Principal component analysis (PCA) revealed the relationships between parameters and applications. The first 3 PCs were important in describing the data. While eight components explained the variation in the data, the first two components explained 90.6% of total variance. PC1 and PC2 accounted for 77.9% and 12.8%, respectively (Table 3). The highest saline dose, 300 mM, was separated by diminish in all traits, as clearly seen in biplot. Vermicompost treatment was clustered into the same group with leaf area index, root length, and root weight. On the other hand, control was characterized by chlorophyll content and leaf weight. Relationships between all traits and applications are shown in Figure 4.

Table 3. Eigenvectors and variances of principal components

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Stem length	0.38	0.01	-0.28	0.39	0.08	0.61	-0.31	-0.38
Root length	0.29	0.66	-0.07	0.32	0.30	-0.11	0.49	0.18
Leaf number	0.38	-0.15	0.20	-0.22	0.70	-0.37	-0.28	-0.20
Leaf weight	0.34	-0.38	-0.48	-0.39	-0.04	0.03	0.58	-0.14
Stem weight	0.39	-0.13	-0.26	-0.01	-0.07	-0.01	-0.34	0.80
Root weight	0.33	0.43	0.37	-0.62	-0.26	0.33	-0.07	-0.03
Chlorophyll content	0.31	-0.44	0.66	0.34	-0.10	0.16	0.32	0.12
Leaf area index	0.38	0.09	-0.04	0.21	-0.58	-0.59	-0.16	-0.31
Variance	77.92	12.76	4.72	1.70	1.32	0.88	0.41	0.30
Cumulative variance	77.92	90.67	95.39	97.09	98.41	99.29	99.70	100.00
P-value	<.0001	<.0001	0.03	0.55	0.52	0.58	0.84	

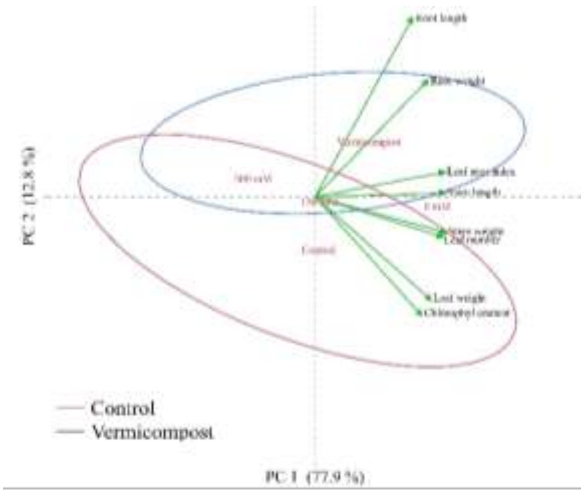

Figure 4. Distribution of parameters on the biplot according to applications.

4. Conclusion

It has been determined that applying the vermicompost gives positive results for the peanut plant grown under saline stress. In future studies, it is possible to obtain more precise results in physical analysis by increasing the application and observation time and by trying different application methods. It is thought that the study's results will be an excellent example of evaluating the resistance of peanuts to saline stress.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The author confirms that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. Ethics committee approval was not required for this study because of there was no study on animals or humans.

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Author Contributions

All tasks made by the single author of the manuscript and the percentage of the author contributions is present below. The author reviewed and approved final version of the manuscript.

	A.Y.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

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