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IMPACT OF PD-04_DR-02_P4 GREEN COVER CROPS ON THE PRODUCTIVITY OF MAIZE HYBRIDS

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Abstract

This study assessed the agronomic and environmental effects of pea (Pisum sativum L.) green cover crops, implemented under the PD-04_DR-02_P4 agri-environmental scheme of the Romanian Strategic Plan (PNS 2023-2027), on drought-tolerant maize hybrids cultivated in the semi-arid Dobrogea region. Field trials (2024-2025) at Săcele, Constanța County, used two Pioneer AQUAmax® hybrids: P8834 (FAO 360) and P9903 (FAO 390), to evaluate the contribution of legume-based cover crops to soil improvement and yield stability. The 2025 season was extremely dry (124 mm rainfall), resulting in severe water stress. Plots previously cultivated with pea produced 25-30% higher yields (1.10-1.30 t ha^{-1}) than the control, due to improved soil friability, 10-12% higher NDVI, and enhanced biological nitrogen input (≈ 30-40 kg N ha^{-1}). The early hybrid P8834 achieved yields comparable to P9903, confirming its drought-escape advantage. These findings demonstrate that integrating pea cover crops with drought-tolerant maize hybrids strengthens soil structure, increases water retention, and stabilizes yield under extreme drought. The results validate the PD-04 eco-scheme as a cost-effective measure for climate-smart agriculture in southern Romania and similar semi-arid regions.

Key words*: biological nitrogen fixation, cover crops, Dobrogea, drought, maize hybrids, PD-04_DR-02_P4.*

INTRODUCTION

Climate change, soil degradation, and water scarcity have become major constraints for sustainable crop production across South-Eastern Europe. In Romania, the Dobrogea region is particularly exposed to these environmental pressures due to its semi-arid continental climate, characterized by high interannual variability of rainfall and frequent summer droughts (Niță et al., 2023). Average annual precipitation rarely exceeds 400 mm, while evapotranspiration often surpasses 800 mm, creating a chronic soil water deficit that severely limits maize (*Zea mays* L.) productivity (Barna & Mănescu, 2025).

The increasing frequency of extreme weather events such as prolonged dry spells, heat waves, and wind erosion, accelerates soil organic matter losses and reduces fertility (Kaye & Quemada, 2017; Scavo et al., 2022). Modern maize cultivation systems increasingly rely on climate-resilient hybrids and adaptive tillage and fertilization strategies to cope with such stress factors (Botoș et al., 2025). According to Moraru, Ene & Badilă (2020), the decline in soil humus content in southeastern Romania correlates with reduced water-storage capacity and deteriorated soil physical structure, demanding integrated agronomic, ecological and policy interventions.

Recent studies analyzing Romanian crop farms before the implementation of the National Strategic Plan (2023-2027) revealed that crop rotations were highly variable and often limited in legume inclusion, emphasizing the need for integrating environmentally beneficial practices such as cover crops (Stoicea et al., 2023).

Within the framework of the Common Agricultural Policy (CAP 2023-2027), Romania has introduced new eco-schemes under the National Strategic Plan (PNS) to incentivize environmentally friendly practices. One such measure is the PD-04 agri-environmental scheme, which promotes the establishment of green cover crops on arable land during winter to reduce erosion, enhance soil organic carbon, and improve biodiversity. Farmers who implement PD-04 commit to maintaining a living vegetal cover between September and

February, terminating it mechanically before 31 March, and refraining from herbicide or ploughing during this period. This measure is fully aligned with the EU Soil Strategy for 2030, aiming to restore degraded soils and increase climate resilience (European Commission, 2021). Despite the wide promotion of PD-04 and other eco-schemes across Romania, field-level evidence of their agronomic performance under real drought conditions remains limited. However, quantitative field-based assessments combining PD-04-compliant cover crops with drought-tolerant maize hybrids under extreme water limitation are still scarce for semi-arid regions of southeastern Europe. Evaluating such measures in semi-arid regions like Dobrogea is therefore essential for validating their practical relevance and economic viability. This study also contributes to the field of land structuration, emphasizing how green cover crops and reduced tillage practices reshape soil physical properties and support sustainable land use under semi-arid conditions.

Cover crops can mitigate drought stress and stabilize maize yields under limited rainfall conditions (Hunter et al., 2021). Among cover crop species, leguminous plants such as pea (*Pisum sativum* L.) are particularly valuable. Pea (*Pisum sativum* L.) is a major leguminous crop with high agronomic value due to its nitrogen-fixing capacity and adaptability to temperate climates (Podea & Cristea, 2023). They provide biological nitrogen fixation, improve soil porosity, and stimulate microbial activity. In addition, legume residues accelerate nutrient cycling and support carbon sequestration, mitigating greenhouse gas emissions (Kaye & Quemada, 2017; Thorup-Kristensen et al., 2020; Scavo et al., 2022). Legume-based cover crops improve soil fertility, nutrient cycling, and overall plant nutrition in temperate and Mediterranean climates (Scavo et al., 2022). Several studies confirm that pea and vetch cover crops enhance water infiltration and retention capacity in light soils under Mediterranean and continental dry climates (Ward et al., 2012; Gabriel et al., 2012; Krstić et al., 2018; Ziche et al., 2024).

In this context, maize cultivation in Dobrogea faces dual constraints: limited rainfall and declining soil fertility. To maintain profitability, farmers increasingly adopt drought-tolerant hybrids and conservation agriculture practices such as minimum tillage and cover crops. Among available maize hybrids, Pioneer P8834 (FAO 360) and Pioneer P9903 (FAO 390), both from the AQUAmax® series, are specifically designed for drought and heat tolerance. According to Corteva Agriscience (2024), P8834 exhibits high water-use efficiency and early maturity, allowing partial escape from summer drought, while P9903 combines strong root architecture with excellent grain potential under moderate stress. Recent advances in remote sensing (e.g., UAV-based NDVI monitoring) enable quantitative assessment of crop response to cover-crop management under stress conditions, offering valuable insights for precision agriculture.

Under these conditions, identifying agronomic practices that simultaneously improve soil functionality and yield stability is essential for maintaining maize profitability in drought-prone farming systems. This study therefore aimed to evaluate the effect of a pea green cover crop, managed under PD-04 provisions, on the productivity of two AQUAmax® maize hybrids under semi-arid field conditions in Săcele, Constanța County (Dobrogea region). The research also sought to quantify the potential contribution of cover crops to soil moisture conservation, nitrogen enrichment, and overall yield stability in a drought-prone environment.

MATERIALS AND METHODS

The field experiment was conducted to assess the agronomic effects of pea (*Pisum sativum* L.) green cover crops on maize hybrids under PD-04_DR-02_P4 management conditions in southern Romania. The experiment was carried out in 2024-2025 on a private farm in Săcele, Constanța County (Dobrogea). The area has a semi-arid continental climate (mean T ≈ 11°C, long-term rainfall ≈ 400 mm). The 2025 season was extremely dry, totaling 124 mm rainfall (Barna & Manescu, 2025). The soil is a calcareous chernozem, medium-textured, slightly alkaline (pH 7.6) (Moise & Lungu, 2013). Similar pedoclimatic conditions and drought-tolerant crop management strategies were previously described for southeastern Romania (Bănică & Marin, 2025).

Consequently, the 2025 season provided a highly restrictive water regime, ideal for evaluating the adaptive response of hybrids and the role of green cover crops in mitigating drought stress. Real-time field data (Figure 1) validated the strong water deficit and justified the low yield potential observed. Such conditions are characteristic of the semi-arid Dobrogea region, where seasonal rainfall frequently falls below 300 mm. Climatic data were retrieved from the local agrometeorological station (ogor.ro platform), confirming the extreme drought conditions (Figure 1).

Figure 1. Drought monitoring data for the maize growing season (April-September 2025) obtained from ogor.ro (Săcele, Constanța County). The total rainfall was 124 mm, with only 1 mm recorded in June

The trial followed a bifactorial randomized block design (Hybrid × Treatment) with three replications. Each experimental plot had a surface area representative of on-farm conditions, ensuring the applicability of results under practical farming systems:

• Factor A (Hybrid): Pioneer P8834 (FAO 360) and Pioneer P9903 (FAO 390)

• Factor B (Treatment): Control - no cover crop; Pea (*Pisum sativum* L.) green cover

Pea was sown at the end of September 2024 (180 kg ha^{-1}) and mechanically incorporated in late February 2025 per PD-04 rules. Maize was sown on mid-April 2025 at 70 000 plants ha^{-1}. Basal fertilization: NPK 15-15-15 (200 kg ha^{-1}) and ammonium nitrate 33.5 % N (150 kg ha^{-1}) at V6 stage. Minimum tillage and uniform crop protection were applied .

Measured parameters: stand uniformity (V3), SPAD/NDVI (V6–VT), ear length, kernels per ear, 1000-kernel weight, and yield (at 14 % moisture). NDVI and SPAD measurements were used as non-destructive indicators of crop vigor and nitrogen status under drought conditions. Data were analyzed by two-way ANOVA (Hybrid × Treatment) and LSD test ($p \leq 0.05$). This methodological approach allowed the integrated assessment of crop performance, soil-related effects, and hybrid response under extreme water limitation.

RESULTS AND DISCUSSIONS

The 2025 maize season was characterized by extremely low rainfall (124 mm), with only 1 mm recorded in June, the critical flowering period, leading to severe drought stress and a clear differentiation among treatments and hybrids. The pea green cover improved soil friability, early rooting, and canopy greenness. Soils beneath cover crops retained more surface moisture and showed better aggregation, consistent with observations by Ward et al. (2012), Gabriel et al. (2012), and Krstić et al. (2018).

Beyond the observed yield response, the beneficial effect of the pea (*Pisum sativum* L.) green cover crop can be explained by specific soil physical and biological mechanisms. Leguminous cover crops develop a dense and finely branched root system that penetrates compacted soil layers and creates continuous biopores. After root decay, these biopores remain functional pathways for water infiltration, gas exchange, and early maize root elongation. Under semi-arid conditions and minimum tillage systems, such biologically induced porosity plays a key role in improving root-soil contact and facilitating access to deeper soil moisture reserves, contributing to greater crop stability under drought stress, as also reported for maize systems transitioning from conventional to minimum tillage in Dobrogea (Stroe & Panaitescu, 2025).

In addition to root-related effects, the incorporation of pea biomass supplied residues

characterized by a low C:N ratio, stimulating microbial activity and enhancing soil aggregate stability. Nitrogen-rich residues favor the production of microbial binding agents that increase cohesion between soil particles, reducing surface crusting and improving soil friability. Similar improvements in soil physical condition under reduced tillage and climate stress were observed in maize cropping systems from southeastern Romania, where biological inputs partially compensated for the reduction of mechanical soil disturbance (Risnoveanu et al., 2023; Stroe et al., 2025). These soil structural improvements translated into measurable differences in maize yield components and grain yield, are presented in Table 1.

Table 1. Effect of pea green cover crop on maize hybrid performance under semi-arid conditions (Săcele, Constanța, 2025)

Hybrid	Treatment	Ear length (cm)	Kernels per ear	1000-kernel weight (g)	Grain yield (t/ha, 14%)
Pioneer P8834	Control	11.8	540	280	0.85
	Pea cover	12.6	580	295	1.10
Pioneer P9903	Control	14.2	610	300	1.00
	Pea cover	15.1	650	310	1.30

On average, the use of pea green cover increased yield by 27 ± 3%, ear length by 6%, and kernel weight by 5%. These improvements are consistent with those reported by Coombs et al. (2017) and Scavo et al. (2022), who found similar yield benefits of legume-based cover crops under Mediterranean drought conditions.

Effect of the cover crop on maize development. Both hybrids emerged uniformly; however, plots sown after the pea (*Pisum sativum* L.) green cover crop showed visibly better soil tilth, darker surface color, and fewer crusted areas, suggesting improved infiltration and water retention. These qualitative field observations were reflected in the higher grain yields recorded in pea-cover treatments for both hybrids, as illustrated in Figure 2.

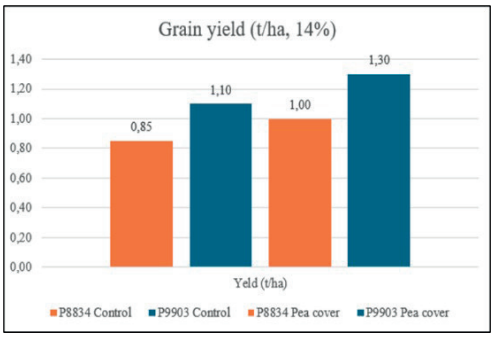

Figure 2. Grain yield response of maize hybrids (Pioneer P8834, P9903) to pea green cover under semi-arid conditions (Săcele, 2025)

The PD-04-compliant cover was incorporated mechanically in late February, allowing partial mineralization of biologically fixed nitrogen before maize sowing.

Hybrid P8834 (FAO 360, AQUAmax®) demonstrated faster early growth and earlier flowering (approx. 5-6 days earlier than P9903), which helped it avoid the peak summer drought. Hybrid P9903 (FAO 390, AQUAmax®) maintained a larger vegetative structure but experienced partial kernel abortion under the prolonged dry period of July-August.

In both cases, the residual nitrogen and improved soil structure from pea biomass contributed to higher SPAD and NDVI values (+8-10%) at the V6 stage compared to the control.

The presence of cover crop residues on the soil surface during early spring further contributed to limiting soil water losses through evaporation, particularly during the V3-V6 maize growth stages. Partial soil shading and reduced temperature fluctuations helped conserve moisture at the soil surface, which is critical for early canopy establishment under semi-arid conditions. Enhanced early vegetative development is known to positively influence kernel formation and thousand kernel weight, especially in short-season hybrids exposed to climatic stress (Mircea et al., 2023). These physiological and developmental responses were reflected in increased ear length, a higher number of kernels per ear, and greater thousand

kernel weight in pea-cover treatments for both hybrids, as shown in Figures 3, 4, and 5.

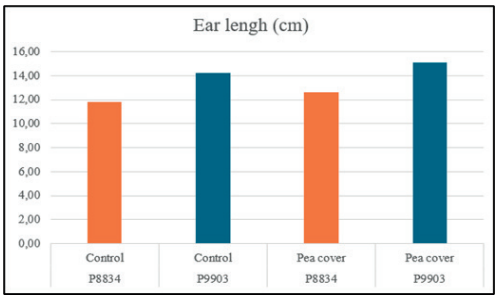

Figure 3. Ear length (cm) of maize hybrids (Pioneer P8834, P9903) (Săcele, 2025)

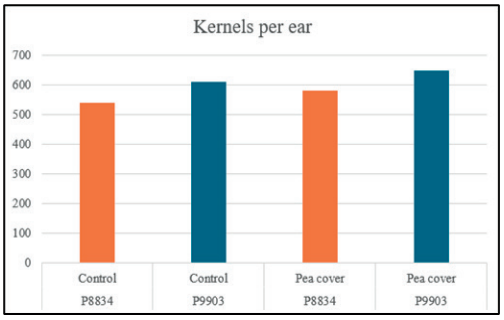

Figure 4. Kernels per ear of maize hybrids (Pioneer P8834, P9903) (Săcele, 2025)

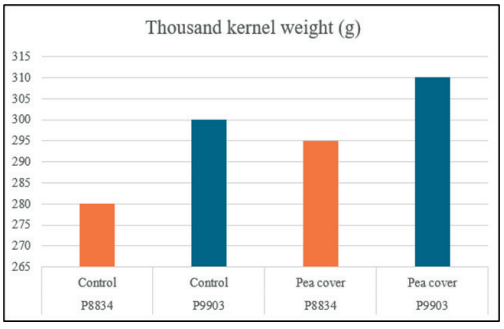

Figure 5. Effect of pea cover crop on 1000-kernel weight

The pea cover increased yields by 25-30%, primarily through higher kernel weight and improved grain filling. Although hybrid P9903 has a higher yield potential under favorable conditions, its advantage was limited under severe drought stress. In contrast, the early-maturing hybrid P8834 achieved comparable yields, confirming its drought-escape efficiency and high water-use performance under restrictive moisture conditions.

The incorporation of pea biomass (≈ 30–40 kg N ha^{-1}) enriched the soil with biologically fixed nitrogen, improved soil porosity, and contributed to yield stabilization, in agreement with previous findings reported by Kaye and Quemada (2017), Coombs et al. (2017), and Scavo et al. (2022). Significant positive correlations were observed between grain yield and NDVI (r = 0.89), as well as between yield and thousand kernel weight (r = 0.86), indicating that canopy greenness and kernel development are reliable indicators of drought resilience and yield potential under semi-arid field conditions. Cover crops thus acted as effective yield stabilizers, improving soil structure and water-retention capacity even under extreme drought conditions. Similar responses have been documented in Mediterranean and continental dryland systems (Ward et al., 2012; Krstić et al., 2018; Ziche et al., 2024). The magnitude of the yield advantage observed in this study (≈ 0.3 t ha^{-1}) is consistent with results reported for legume-based cover crops under water-limited environments and highlights the capacity of PD-04-compliant practices to deliver agronomic benefits alongside environmental compliance.

These results emphasize the complementary effects of short-season maize hybrids and leguminous cover crops in maintaining yield stability under limited rainfall. The yield advantage can be largely attributed to the nitrogen credit supplied by pea biomass and improved soil moisture conservation during early maize growth stages, when crop sensitivity to water stress is particularly high.

Moreover, PD-04-compliant management practices, maintaining the cover crop over winter and incorporating it mechanically before 31 March, proved fully compatible with the maize cropping calendar in Dobrogea, without delaying sowing or crop establishment.

From a land structuration perspective, the consistent improvements in soil friability, aggregate stability, and biological porosity observed in pea-cover treatments confirm that legume-based green cover crops can partially substitute mechanical soil structuring traditionally achieved through intensive tillage. Biological structuring driven by root development, residue decomposition, and microbial activity enhances soil resilience under repeated drought cycles, supporting sustainable

land management in degraded dryland agroecosystems. The positive effect was particularly evident for the early hybrid P8834, which avoided peak drought periods due to its shorter vegetative cycle. Overall, these findings confirm that the integration of PD-04-compliant green cover crops contributes not only to soil fertility and drought mitigation but also supports the EU CAP 2023-2027 objectives for sustainable agriculture in semi-arid regions.

Under the extreme pedoclimatic conditions recorded in 2025, this study provides field-level evidence that the agronomic benefits of legume-based green cover crops persist even under severe water limitation. By combining drought-tolerant maize hybrids with PD-04-compliant soil management practices, it was possible to achieve measurable yield stabilization and improved soil functionality, reinforcing the role of eco-schemes as practical tools for climate-adaptive agriculture in semi-arid regions.

CONCLUSIONS

The 2025 maize season in Dobrogea was characterized by extreme pedological drought, with only 124 mm of rainfall during the crop cycle. Under such restrictive conditions, the use of pea (*Pisum sativum* L.) green cover crops, managed according to the PD-04 agri-environmental scheme, enhanced soil structure, plant vigor, and grain yield. Beyond yield improvement, pea green covers significantly contributed to land structuration by reinforcing aggregate stability and biological porosity. These effects promote erosion resistance, infiltration efficiency, and long-term soil health under repeated drought cycles. Yield increases of 25-30% were recorded in pea-cover plots, mainly due to improved soil water retention and biological nitrogen input.

Between the tested hybrids, Pioneer P8834 (FAO 360, early-maturing AQUAmax®) demonstrated superior adaptability and yield stability compared with P9903, confirming the advantage of short-season genotypes under severe water stress conditions.

Overall, the results demonstrate that integrating legume-based green cover crops with drought-tolerant maize hybrids represents a viable and cost-effective strategy for stabilizing production in semi-arid regions. The findings provide field-based evidence that PD-04-compliant practices can deliver both agronomic and environmental benefits under real farm conditions, supporting their wider adoption within the CAP 2023-2027 framework. Further research should focus on quantifying long-term impacts on soil organic carbon dynamics, nutrient cycling efficiency, and farm-level economic performance to strengthen decision-making for sustainable dryland agriculture.

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